Lower Chickahominy River and Tributaries Bacteria TMDL Technical Advisory Committee (TAC) Meeting

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Why We Are Here

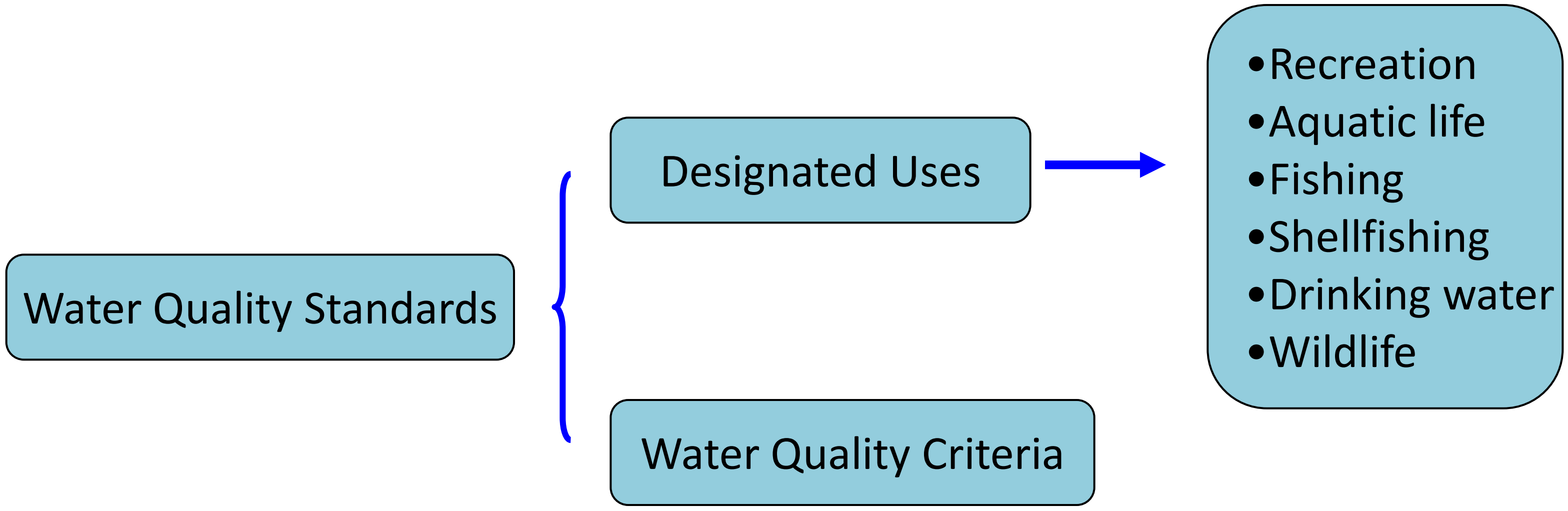
1. To review the final source assessment methods and results
2. To review the watershed, hydrodynamic, and water quality modelling results
3. To review the TMDL results
4. To gather feedback and technical advice

Outline

- The TMDL process
- Impaired waters and pollutants
- Source assessment methods and results
- Modeling methods and results
- TMDL results
- Discussion

The TMDL Process

- DEQ routinely monitors the quality of waters across the state and publishes a list of impaired waters every 2 years
- VA is required by law to establish a TMDL for each pollutant causing an impairment
- A TMDL is the amount of a particular pollutant that a stream can receive and still meet WQSs
- WQSs are regulations based on federal or state law that set numerical or narrative limits on pollutants



What is a TMDL ?
Total Maximum Daily Load

A TMDL is the amount of a particular pollutant that a stream can receive and still meet Water Quality Standards

AKA "Pollution Diet"

TMDL = Sum of WLA + Sum of LA + MOS

Where:

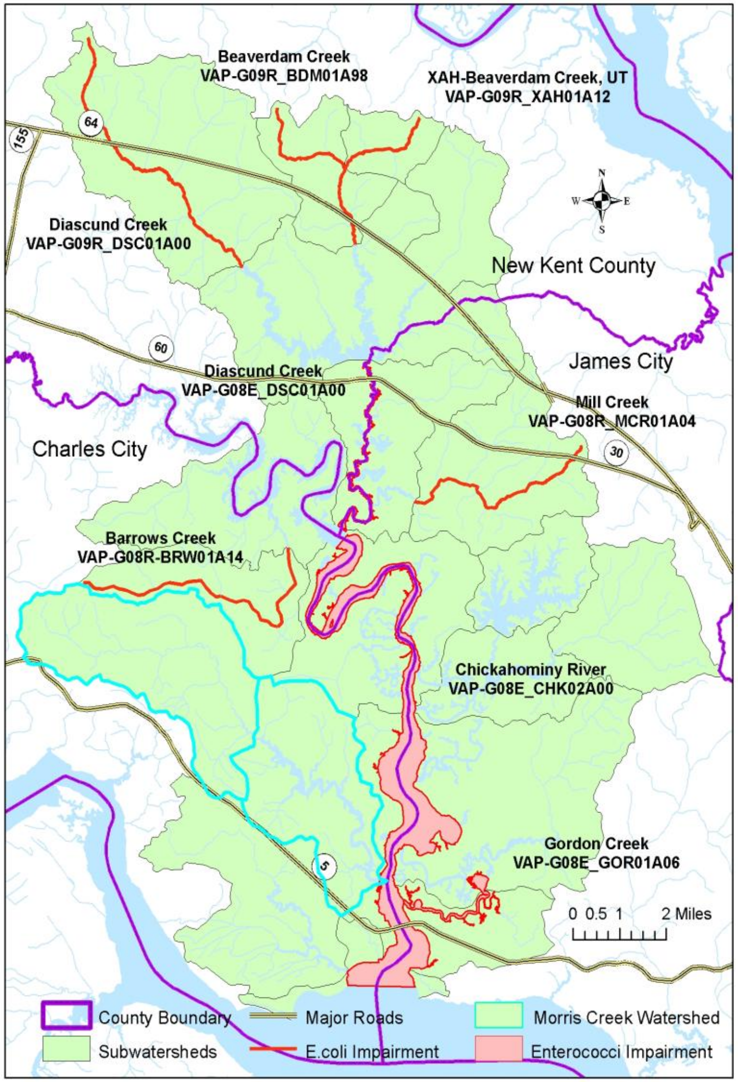
TMDL = Total Maximum Daily Load
WLA = Waste Load Allocation (point sources)
LA = Load Allocation (nonpoint sources)
MOS = Margin of Safety

Current Load = current loads discharged to the water body, which will be determined during this study

Reduction = (current load –TMDL)/ current load x 100%

Impaired waters and pollutants

- Lower Chickahominy River and seven tributaries are Impaired for elevated bacteria levels
- The Morris Creek bacteria TMDL study was completed in 2009. The estimation of the source was input to the watershed model to derive daily loading for the estuary. However, the TMDL will be changed.



Water Quality Criteria

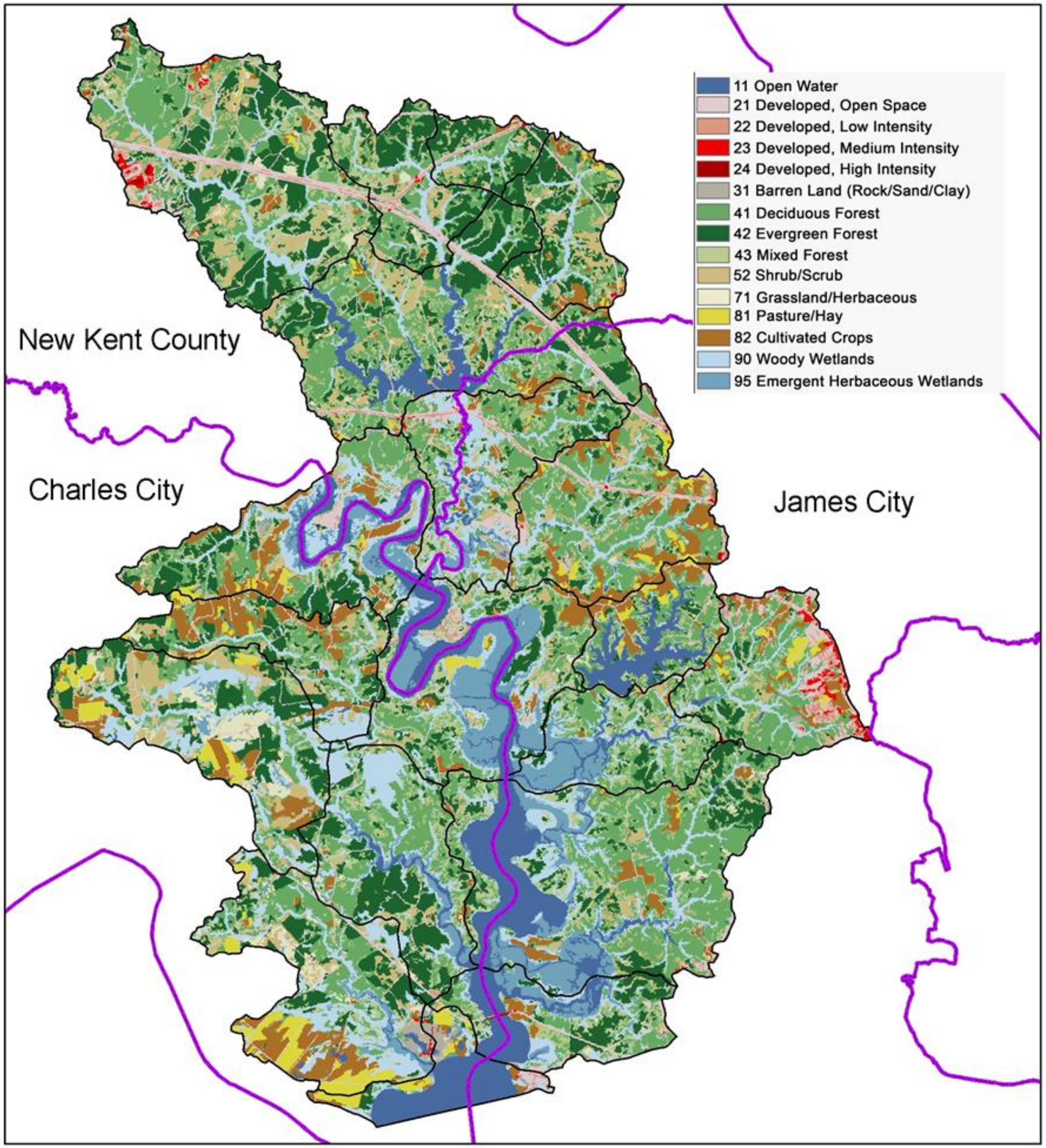
Use	Indicator Bacteria	Criteria
Recreation	*E. Coli* (freshwater)	Geometric Mean 126 counts/100ml * Single Sample Maximum 235 counts/100ml
	Enterococci (transition & salt water)	Geometric Mean 35 counts/100ml * Single Sample Maximum 104 counts/100ml

- *If there are insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 235 E.coli counts/100 ml .*

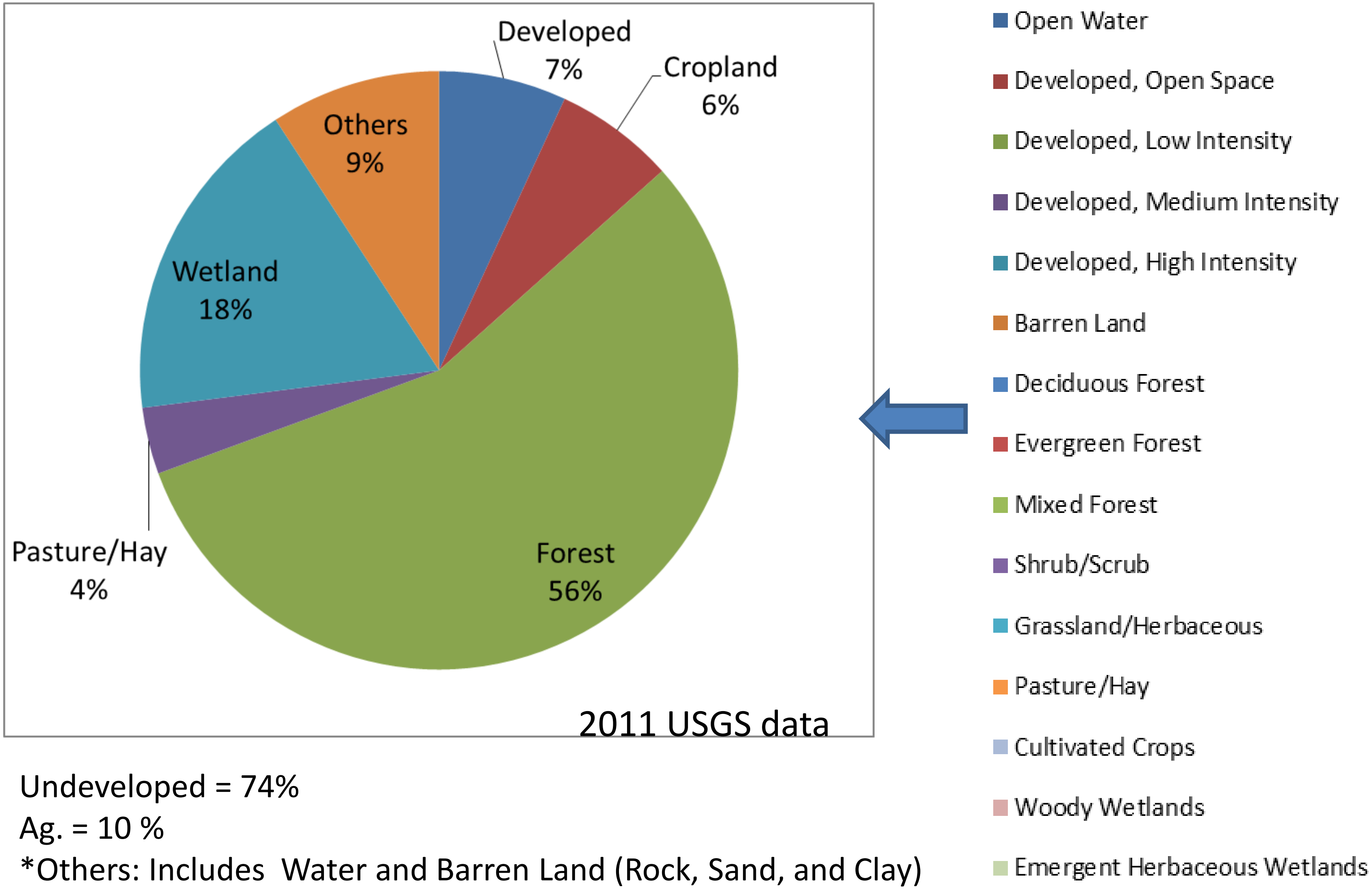
*** If there are insufficient data to calculate monthly geometric means in transition and saltwater, no more than 10% of the total samples in the assessment period shall exceed enterococci 104 counts/100 ml.*

Land Use

(USGS NLCD 2011 data)



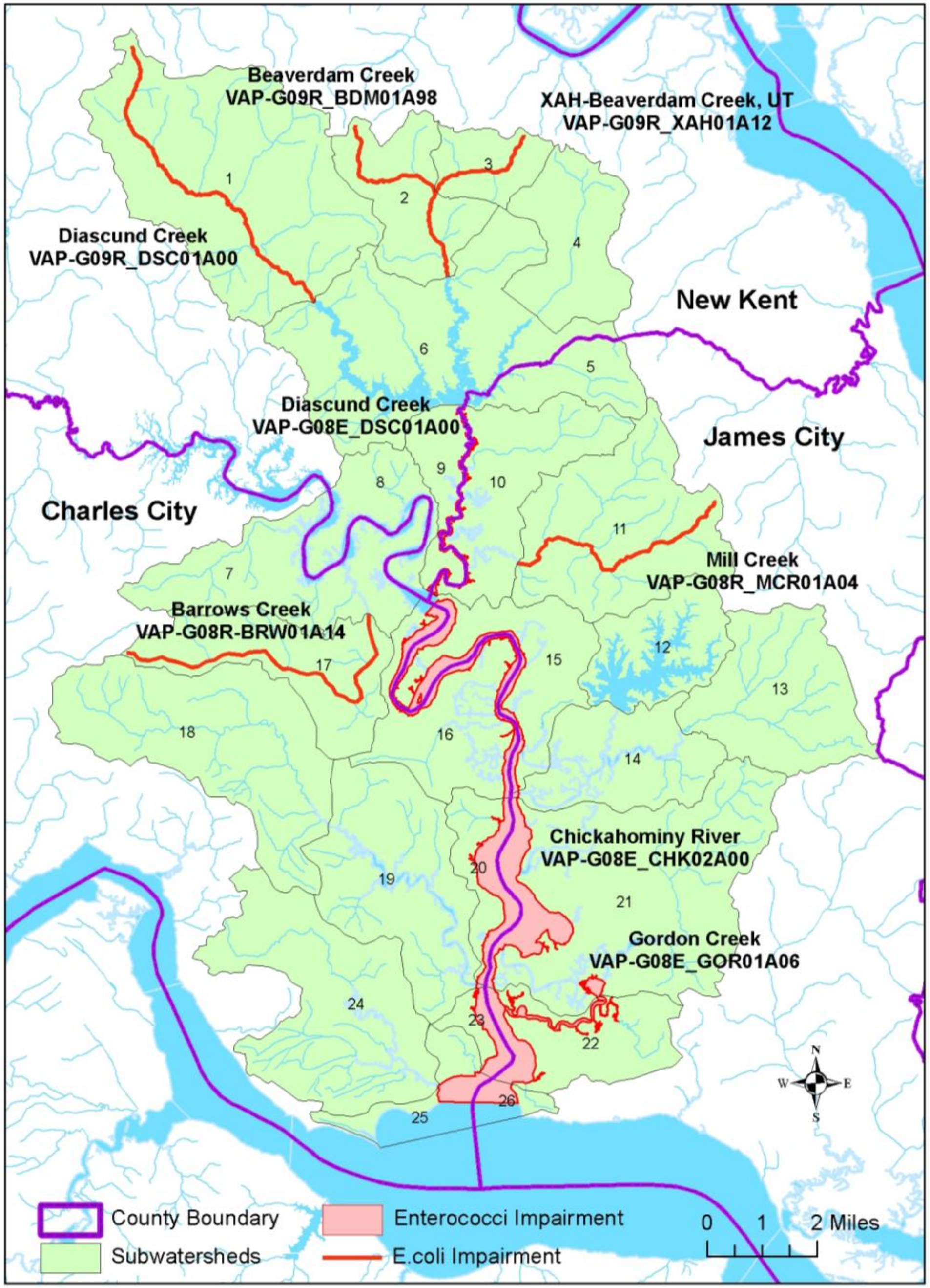
Land Use Distribution



Undeveloped = 74%
Ag. = 10 %
*Others: Includes Water and Barren Land (Rock, Sand, and Clay)

Subwatershed Delineation for Source Assessment and Modeling Purposes.
There are a total of 26 segments

Area	Subwatersheds
Chickahominy River	1-26
Diascund Creek (nontidal)	1
Beaverdam Creek	2, 3
UT Beaverdam Creek	3
Diascund Creek (tidal)	1-6,9-11
Mill Creek	11
Barrows Creek	17
Gordon Creek	22
Charles City County	7, 16-20, 23-25
James City County	5, 10-15,21,22,26
New Kent County	1-4, 6, 8, 9



Procedures of Source Assessment

- Sources
  - Point Source: any discernible, confined and discrete conveyance, from which pollutants are or may be discharged.

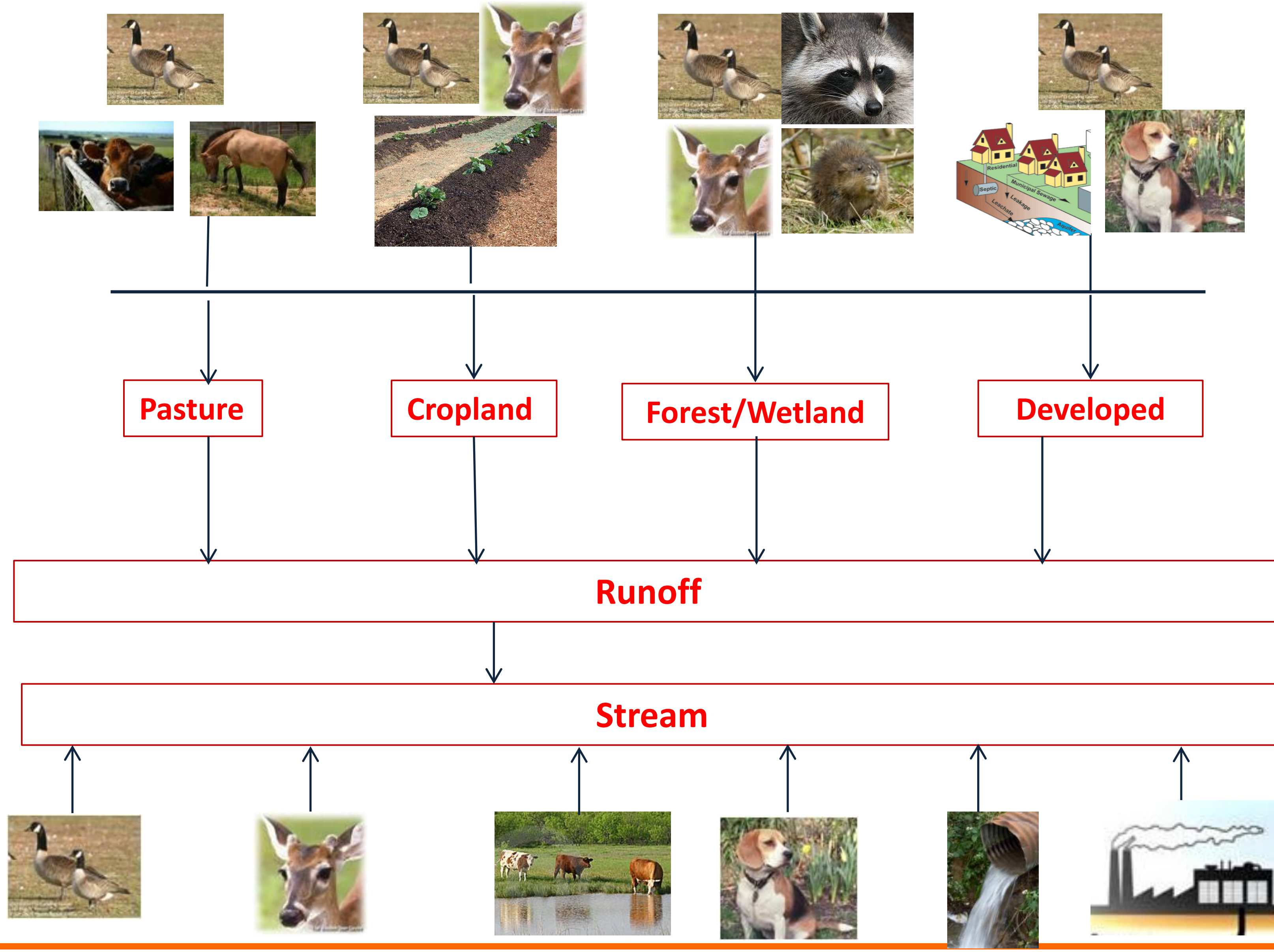



  - Non-point Source: any source of water pollution that does not meet the legal definition of "point source“.
    - Agricultural/Livestock
    - Humans
    - Pets
    - Wildlife



- Approach
  - GIS data (land use, population, pets, septic systems, pervious and impervious, roads, etc.)
  - Field survey
  - Census of Agriculture data
  - Wildlife survey data (animal density, animal habitat)
  - DEQ and DCR database (point source, nutrient management, AFO, CAFO)
  - Virginal Health Department (SSO, shoreline survey)
  - Public inputs/Public meeting/Interview with local citizens

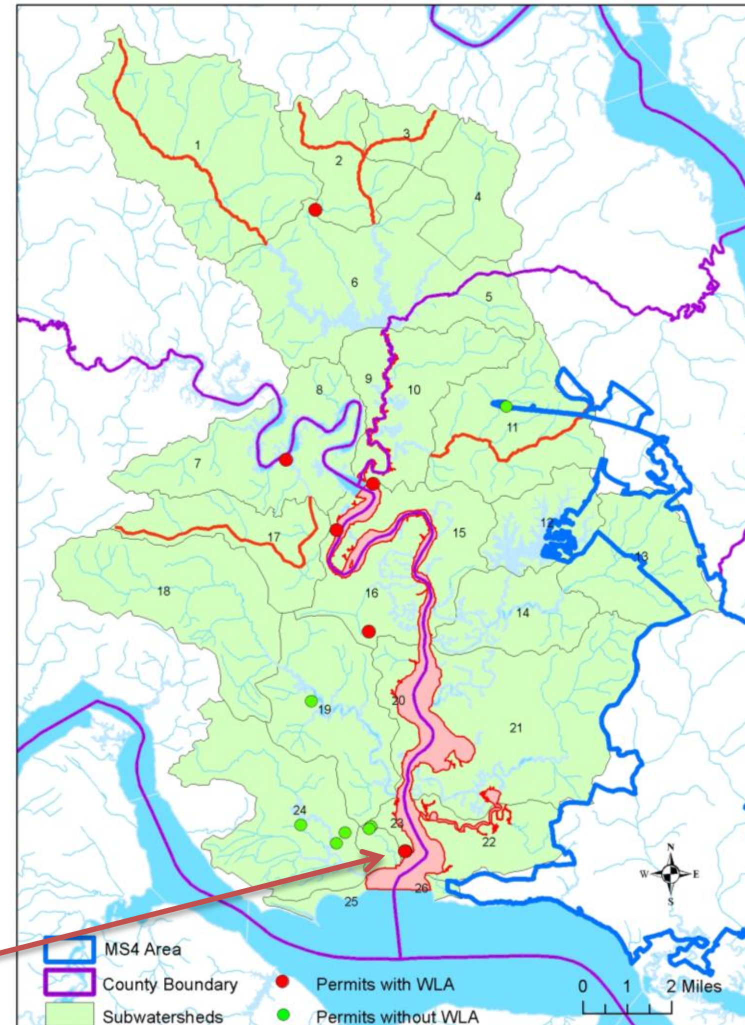
Potential Sources



Point Source

14 permitted; 9 will receive WLAs

Permit Number	Facility Name	Permit Type	Category	Sub-watershed
VA0080233	Hideaway STP	Municipal	VPDES-IP	16
VAG403039	Single Family Home	General	Domestic Discharger	15
VAG404050	Single Family Home	General	Domestic Discharger	16
VAG404144	Single Family Home	General	Domestic Discharger	23
VAG404152	Single Family Home	General	Domestic Discharger	23
VAG404198	Single Family Home	General	Domestic Discharger	7
VAG404284	Single Family Home	General	Domestic Discharger	6
VAR040037	Locality urbanized Service area -James City	General	MS4-Phase II	Part of 11, 12, and 13
VAR040115	VDOT roads Within James City County	General	MS4-Phase II	Part of 11, 12, and 13



2 facilities that are very close to each other

Preliminary Results of Load Reduction and Allocation *(Point Sources)*

- For the one VPDES-IP *permit,* baseline load is calculated as mean measured concentration multiplying mean measured flow, and WLA as bacteria limit multiplying designed flow.

Permit #	Designed Flow (MGD)	DMR Parameter	Existing Load (Count/Day)	WLA (Count/Day)	% Reduction
VA0080233	0.039	Enterococci	2.0E+07	5.2E+07	0

- For the 6 domestic dischargers, the DMRs are not available. Both the baseline loads and WLAs are calculated as designed flow multiplying bacteria limit. Example-

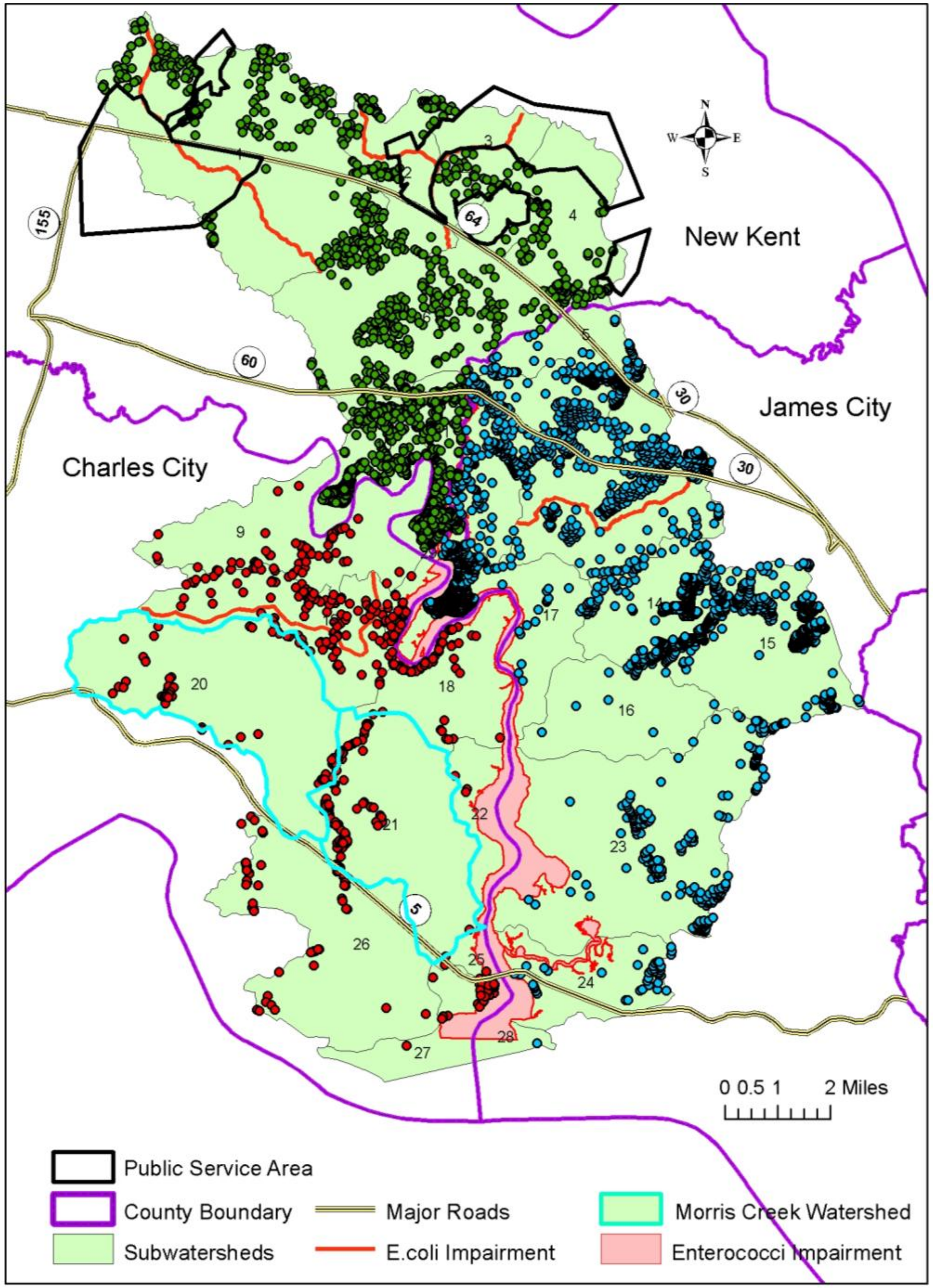
Permit #	Designed Flow (MGD)	DMR Parameter	Existing Load (Count/Day)	WLA (Count/Day)	% Reduction
VAG404284	0.001	*E.coli*	8.9E+06	8.9E+06	0

- For the 2 MS4s, both the baseline loads and WLAs will be based on the modeling result.

Non-Point Sources

1. Human Source --- Septic Tanks

- **James City County**
  - Based on the GIS layer of septic tank locations
  - A small portion of “urban” land area is associated with storm water management
- **New Kent and Charles City Counties**
  - Based on the “911” street address GIS layers
  - Public service areas in New Kent excluded
  - Morris Creek result adopted



Estimated Number of Septic Tanks by Subwatershed

Subwatershed	Number of Septic Tanks	Subwatershed	Number of Septic Tanks
1	268	14	61
2	106	15	439
3	20	16	83
4	101	17	114
5	64	18 and 19 (Morris Creek)	97
6	346		
7	58	20	4
8	382	21	195
9	271	22	41
10	435	23	38
11	400	24	57
12	289	25	8
13	436	26	1

For All 3 Counties

After obtaining the number of septic tanks …

1. # Failing septic tanks = # septic tanks * failure rate (10%, James City County data)
2. # people served = # Failing septic tanks * # persons/household (USCB 2015)
3. Septic Flow = # people served * Septic flow rate (70 Gal/Person/Day, EPA 2001)
4. Fecal Coliform Loading (Counts/Day) = Septic Flow * Septic Concentration (1.0×10^{6} #/100ml, MapTech 2010)

1. Human Source --- Boating Activity/Marina

1. Obtain # of boats in each county *(VA-DGIF)*

- # of boats in subwatershed = # of boats in county / county open water area * subwatershed open water area

2. Parameters used: (VDH; Poquoson River TMDL, VA-DEQ 2014)

- An average of 3 persons per boat
- Only 10% of the boats contribute to the loading
- A production rate of 2.0E+09 counts/day/person

3. Fecal Coliform Loading (Counts/Day) =

*# Boats * 10% * 3 (persons) * 2.0×10^9 (counts/day/person)*

Estimated Number of Boats in Each Subwatershed

Subwatershed	Number of Boats	Subwatershed	Number of Boats
1	4	14	36
2	0	15	111
3	0	16	80
4	2	17	2
5	15	18 and 19 (Morris Creek)	27
6	366		
7	56	20	85
8	157	21	244
9	36	22	100
10	31	23	35
11	5	24	14
12	145	25	104
13	5	26	60

1. Human Source --- Straight Pipes

Untreated or raw sewage directly discharged by house pipe to a waterway

- Utilize percent distribution noted from 1990 Cencus (1.90% for straight pipes for VA) (USCB 2011)
- # of Persons Utilizing Straight Pipes = # of Persons per Household * # of Houses * 1.90%
- Water Discharge Rate = 70 Gallons/Person/Day (EPA 2001)
- Raw Sewage Fecal Coliform Concentration = 2,700,000 MPN/100ml (DEQ 2014)
- Fecal Coliform Load (Counts/Day) = # of Persons Utilizing Straight Pipes * Water Discharge Rate * Raw Sewage Concentration

Estimated Number of Straight Pipes in Each Subwatershed

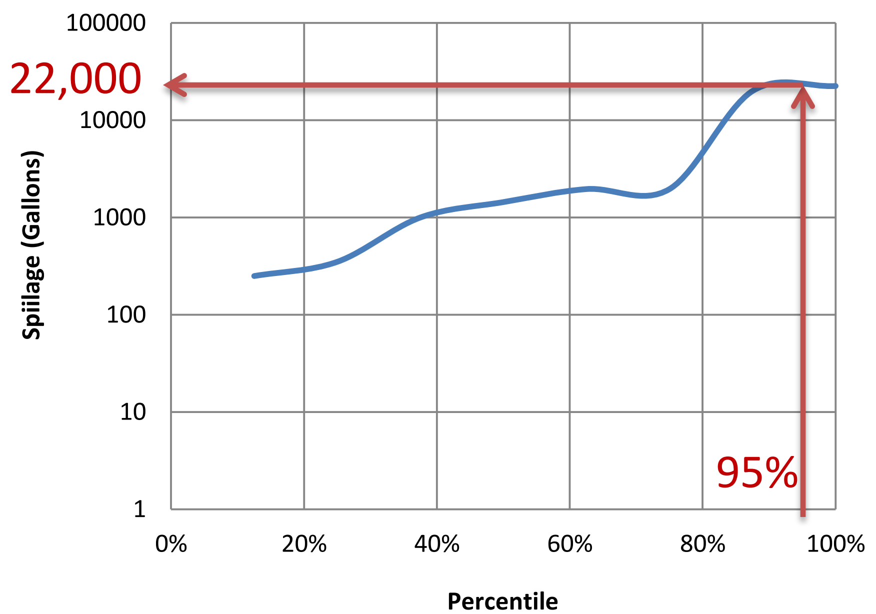
Subwatershed	Number of Straight Pipes	Subwatershed	Number of Straight Pipes
1	5	14	1
2	2	15	8
3	0	16	2
4	2	17	2
5	1	18	1
6	7	19	2
7	1	20	0
8	7	21	4
9	5	22	1
10	8	23	1
11	8	24	1
12	5	25	0
13	8	26	0

1. Human Source ---SSOs

Permit No	Permitee	Date of SSO	Subwatershed	Volume (Gallons)
VA0080233	Hideaway STP	2/5/2010	18	500-1000
VA0080233	Hideaway STP	8/27/2011 -/1/2011	17	1400-20000
VA0080233	Hideaway STP	7/31/2013 -/5/2013	16	22500
VA0080233	Hideaway STP	11/20/2013	18	None reported
VA0080233	Hideaway STP	9/25/2013	18	250
VA0080233	Hideaway STP	1/29/2014	18	350
VA0080233	Hideaway STP	3/8/2014	18	None reported
VA0080233	Hideaway STP	9/3/2014	18	<1440

The accumulative spillage distribution plot method (DEQ, 2014)

The loading corresponding to a 95% spillage volume (22,000 gallons) is estimated as 25% raw sewage and 75% non-raw sewage (DEQ)



Fecal Coliform Information for SSOs

95% Volume (Gallons)	Raw Sewage (25%) Concentration (Counts/100ml)	Non-Raw Sewage (75%) Concentration (Counts/100ml)	Fecal Coliform Load (Counts/Day)
22,000	2,700,000	500,000	8.7×10^{11}

The total loading is distributed to each SSO according to their volume ratio.

Because SSOs occurred only a few days each year, it does not contribute significantly to mean daily variation.

1. Human Source --- Biosolids

Biosolid Fecal Coliform Concentration = 157,835 cfu/g

(Average of measured concentrations observed in several years of samples by VA-DEQ)

Subwatershed	Year	Total Biosolid Application Weight (Wet Tons)	Fecal Coliform Load (Counts/Day)
7	2010	726	3.1×10^{11}
	2014	469	2.0×10^{11}
17	2014	2,329	1.0×10^{12}
18	2010	991	4.3×10^{11}
	2011	934	4.0×10^{11}
	2014	1,195	5.2×10^{11}

2. Pet Source (Dogs)

1. Obtain # dogs (i.e., # of licenses) (from the County Treasurer Office)
2. # Dogs in Subwatershed = # Dogs in County / County Urban Area * Subwatershed Urban Area
3. Fecal Coliform Loading (Counts/Day) = Production Rate (4.0E+09 counts/animal/day, (LIRPB, 1978)) * # Dogs in Subwatershed
4. Only 23% of the total dog feces are subject to runoff (VA-DEQ, 2014)
5. Morris Creek result is used (Subs 18/19)

Estimated Number of Dogs by Subwatershed

Subwatershed	Number of Dogs	Subwatershed	Number of Dogs
1	371	14	8
2	101	15	29
3	47	16	52
4	72	17	78
5	29	18 and 19 (Morris Creek)	425
6	179		
7	52	20	13
8	61	21	40
9	59	22	27
10	57	23	13
11	82	24	130
12	23	25	19
13	157	26	11

3. Wildlife

Densities and Fecal Coliform Production Rates

Species	Density	Reference of Density	Production Rate (Counts/Animal/Day)	Reference of Production Rate
Deer	Charles City: 33/mile^2 James City: 26/mile^2 New Kent: 31/mile^2	VADGIF, 2007	5.00E+08	VADEQ, 2007
Duck	1.532/km^2	VADEQ, 2009	2.43E+09	VA Tech, 2000
Goose	1.969/km^2	VADEQ, 2009	4.90E+10	USEPA, 2001b
Beaver	4.8/mile	VADEQ, 2009	2.50E+08	ASAE, 1998
Raccoon	Inside Buffer: 0.078/acre Outside Buffer: 0.016/acre	VADEQ, 2014	1.25E+08	EPA EXCEL Spreadsheet “FecalTool”
Muskrat	10/acre	VADEQ, 2009	3.40E+07	VADEQ, 2007

3. Wildlife --- Deer

1. Habitat is the entire watershed, except open water and urban
2. Obtain an average deer index by county from VA-DGIF
3. Deer Density = (-0.64 + (7.74 * average deer index))
4. # Deer in subwatershed = Deer Density * Habitat Area in Subwatershed
5. Fecal Coliform Loading (Counts/Day) = # Deer * Production Rate

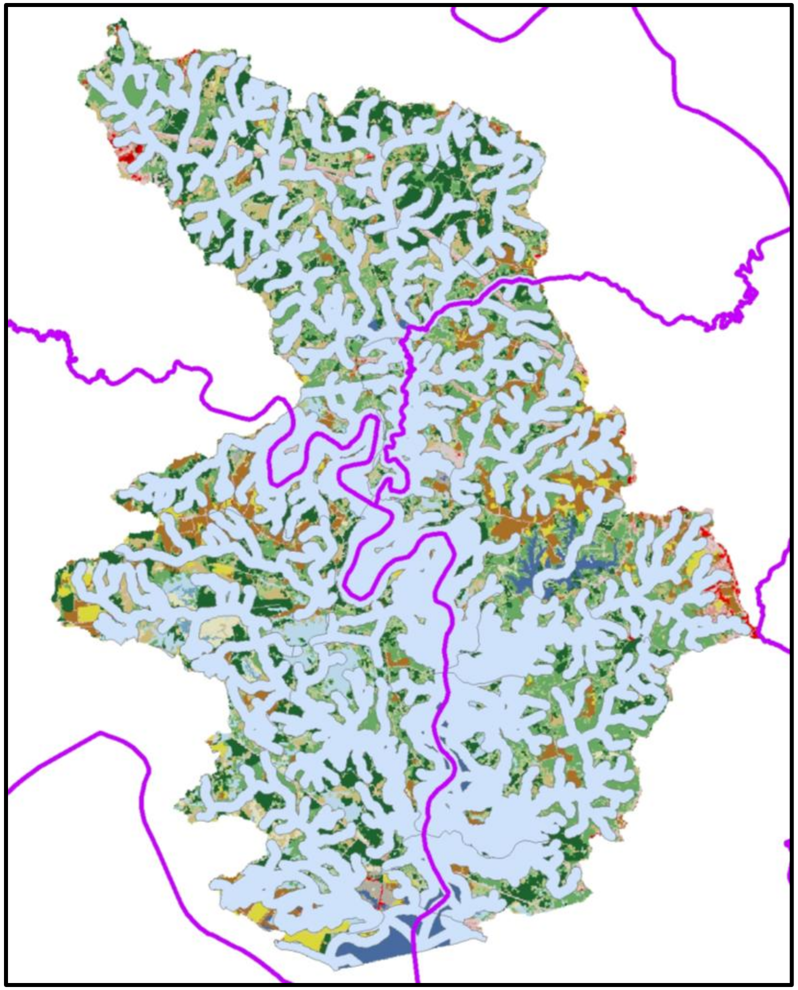
3. Wildlife --- Beaver

1. # Beavers in Each Subwatershed = Average Density * Total River Miles of the Subwatershed

2. Fecal Coliform Loading (Counts/Day) = # Beavers * Production Rate

3. Wildlife --- Raccoon

1. Habitat: wetlands and forest
2. A 600-ft buffer along the streams and ponds
3. Different densities inside and outside of the buffer
4. # of Raccoons = (Habitat area inside the buffer * density inside) + (Habitat Area outside * density outside)
5. Fecal Coliform Loading (Counts/Day) = # of Raccoons * Production Rate



3. Wildlife --- Muskrat

1. Habitat: wetland
2. Habit: most active at night, prolific breeders
3. # of Muskrats = Habitat Area * Density
4. Fecal Coliform Loading (Counts/Day) = # of Muskrats * Production Rate

3. Wildlife --- Geese and Ducks

- Habitat is the entire watershed for both
- # Geese (Ducks) in each subwatershed = Goose (Duck) Density * Subwatershed Area
- Loading (Counts/Day) = # Geese (Ducks) * Production Rate
- Seasonality: Based on the monthly distributions of bacterial concentrations, no persistent seasonality can be seen

We need input about seasonality of the birds

http://justinhackworth.com/goose.html

Estimated Wildlife Numbers by Sub-watershed

Subwatershed	Deer	Duck	Goose	Beaver	Raccoon	Muskrat
1	434	63	81	33	449	8,220
2	135	19	25	21	136	2,893
3	64	9	12	11	65	1,381
4	145	20	26	18	138	2,513
5	58	11	14	10	65	1,337
6	327	51	66	192	318	5,446
7	210	29	38	54	205	10,359
8	71	13	17	54	82	6,218
9	54	9	11	42	67	4,041
10	136	25	32	42	181	10,179
11	221	38	48	23	241	6,665
12	73	18	23	165	31	585
13	142	29	37	20	166	4,254
14	129	22	28	66	192	11,513
15	110	22	29	42	152	10,748
16	151	23	30	42	172	14,329
17	192	25	32	32	133	5,667
18 and 19 (Morris Creek)	450	50	65	65	500	9,800
20	47	10	13	19	48	1,332
21	348	65	83	43	466	25,277
22	93	19	25	67	110	7,995
23	16	4	5	9	17	752
24	321	42	54	38	226	15,018
25	40	10	13	6	20	1,386
26	4	3	4	4	5	578

4. Livestock

Habitat Type and Fecal Coliform Production Rate (ASAE, 1998)

Livestock	Habitat	Production Rate (Counts/Animal/Day)
Beef Cattle	Pastureland, feedlots	1.04E+11
Milk Cattle	Feedlots	1.01E+11
Pigs	Feedlots	1.08E+10
Chickens	Feedlots	1.36E+08
Horses*	Pastureland, feedlots	4.20E+08
Sheep/Goats	Pastureland, feedlots	1.20E+10

*Horses aren't technically a "livestock" animal. Costshare for horse BMPs tends to be more limited than for typical livestock animals.

1. Obtain the # livestock in each county (USDA 2012 Census of Agriculture)
2. # Livestock in Subwatershed = # Livestock in County / County Area * Subwatershed Area
3. Numbers validated and updated by consulting with the citizens
4. Adopted Morris Creek TMDL result (Subs 18/19)






Estimated Livestock Numbers by Sub-watershed

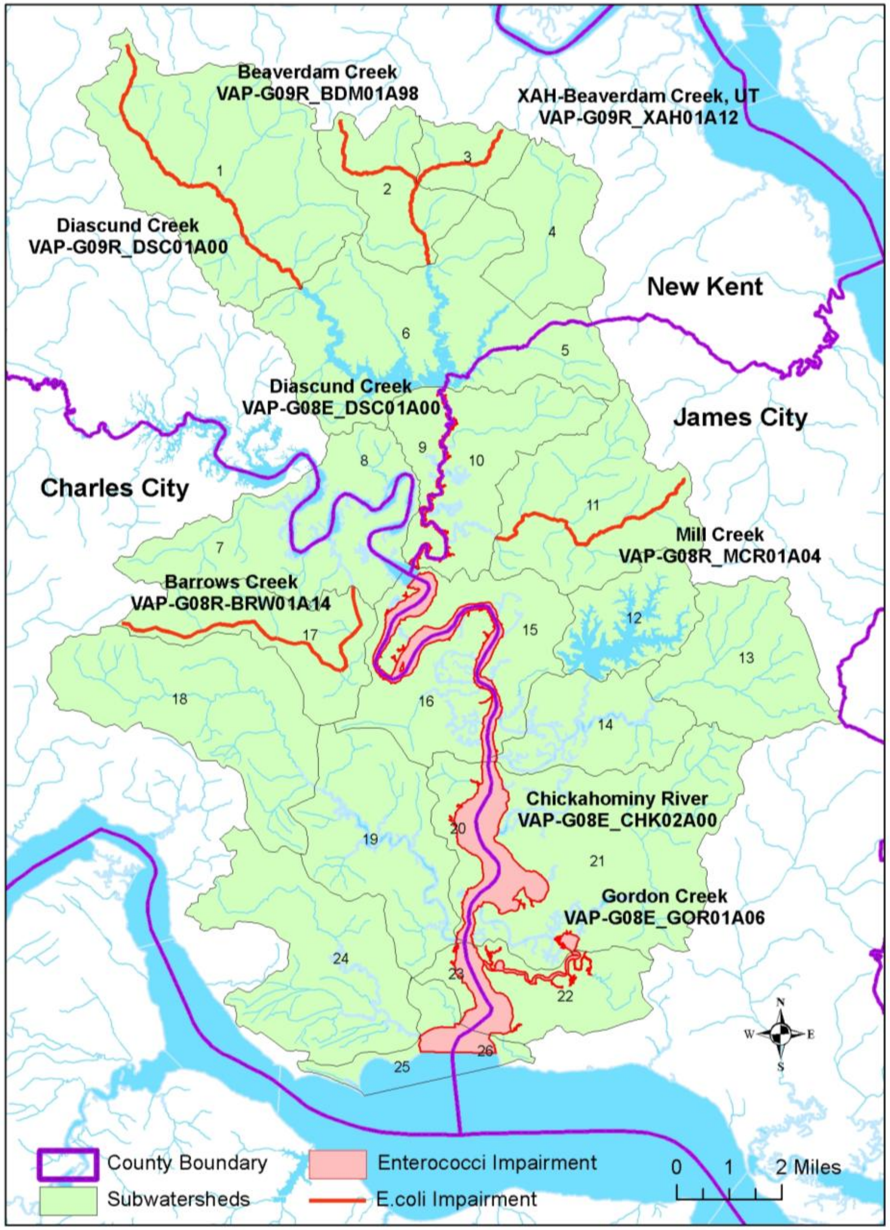
Subwatershed	Beef Cattle	Milk Cattle	Pigs	Chickens	Horses	Sheep/Goats
1	0	1	0	0	0	0
2	0	1	0	0	0	0
3	0	0	0	0	0	0
4	0	1	0	0	0	0
5	2	1	1	19	3	0
6	0	1	0	0	0	0
7	0	0	0	0	0	0
8	0	1	0	0	0	0
9	0	0	0	0	0	0
10	2	2	1	34	4	0
11	30	22	2	68	51	1
12	14	10	1	24	24	0
13	20	15	2	52	35	0
14	2	1	1	26	3	0
15	2	2	1	23	4	0
16	0	6	0	0	0	100
17	45	6	0	0	0	100
18 and 19 (Morris Creek)	20	0	0	20	1	185
20	0	0	0	0	0	0
21	11	8	3	80	18	0
22	1	1	1	21	2	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	1	0	0

- Numbers in green are based on citizen update in the first TAC meeting.
- Numbers in blue are based on the updates from an ANR Extension Agent.
- Numbers in red are based on USDA county data and will be further confirmed by counties. (These livestock loadings are not included in the model, but they are included in the source assessment.)
- Morris Creek TMDL results are adopted.

Any input?

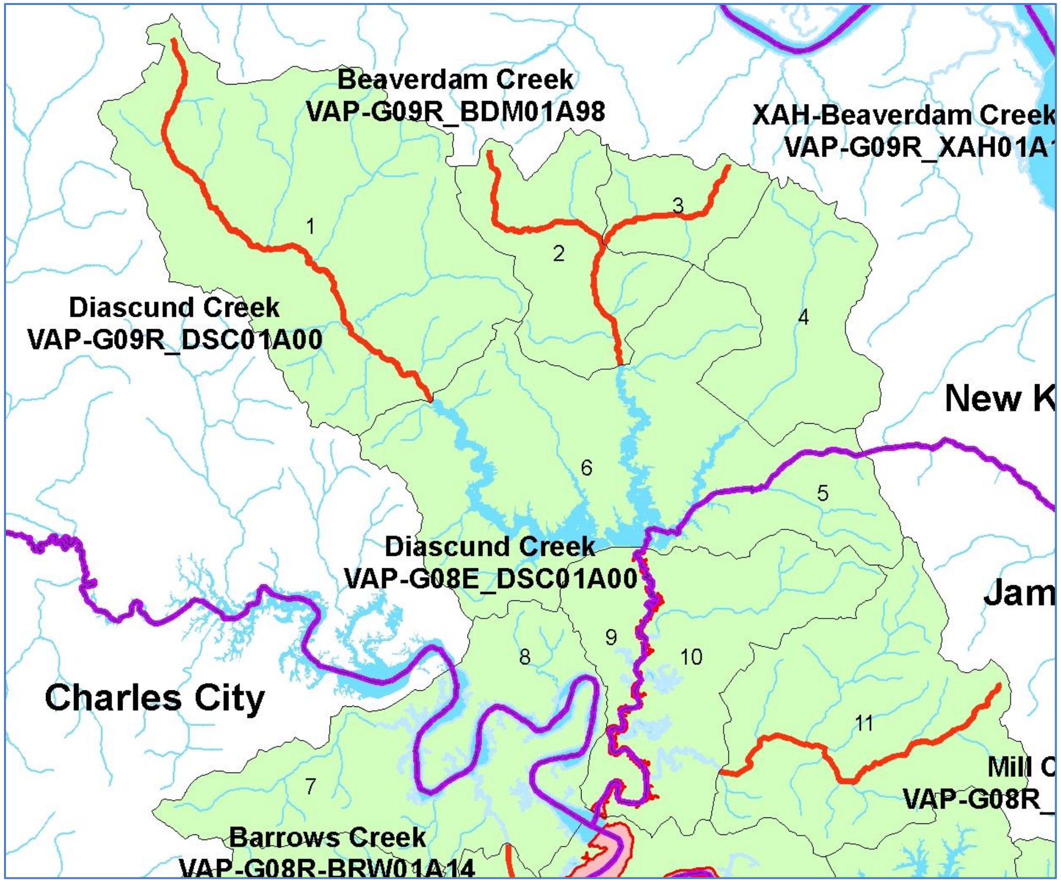
Source Assessment Summary --- by Impaired Water*

Impaired Water	Source	Percentage of Total Load
Lower Chickahominy River (Subwatersheds 1-26)	Wildlife	65.1%
	Livestock	19.8%
	Pets	2.6%
	Humans	14.9%
	Totals	100%

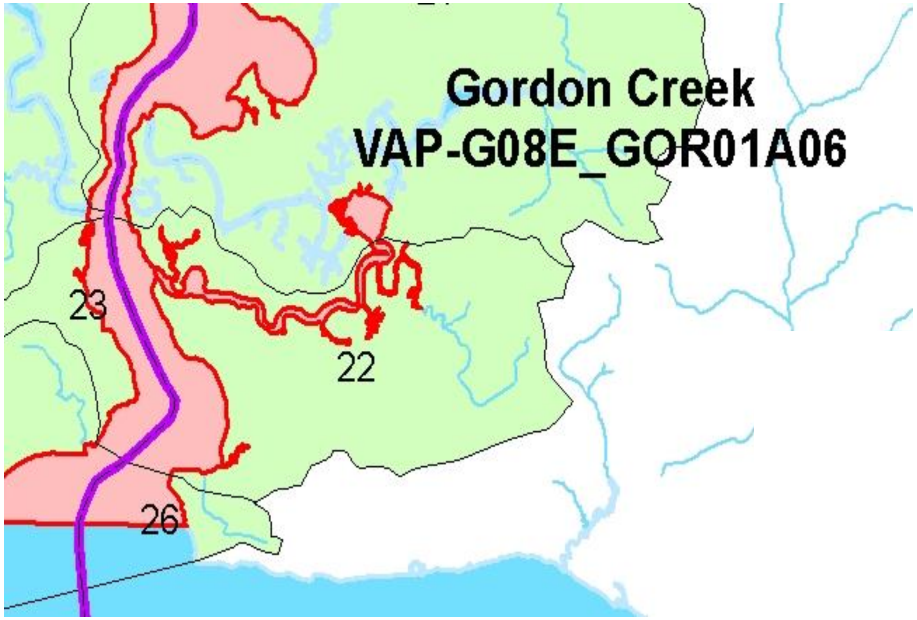


* Based on TAC feedback, these % load contributed are subject to change.

Impaired Water	Source	Percentage of Total Load
Diascund Creek (Tidal) (Subwatersheds 1-6, 9-11)	Wildlife	75.8%
	Livestock	9.8%
	Pets	3.8%
	Humans	10.6%
	Totals	100%



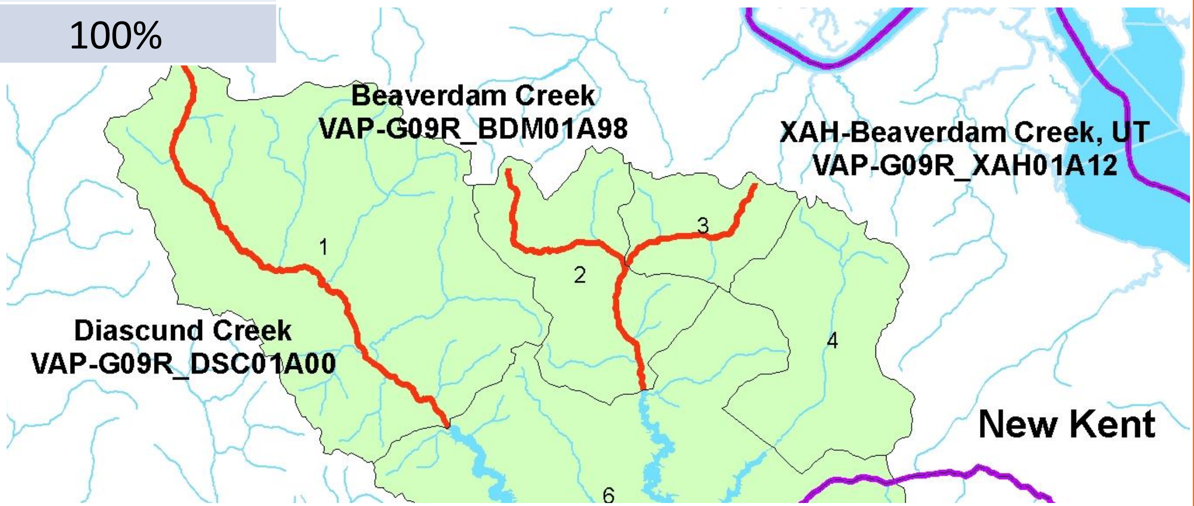
Impaired Water	Source	Percentage of Total Load
Gordon Creek (Subwatershed 22)	Wildlife	88.0%
	Livestock	5.1%
	Pets	1.4%
	Humans	5.6%
	Totals	100%



Impaired Water	Source	Percentage of Total Load
Diascund Creek (Non-Tidal) (Subwatershed 1)	Wildlife	85.0%
	Livestock	0.0%
	Pets	6.3%
	Humans	8.7%
	Totals	100%

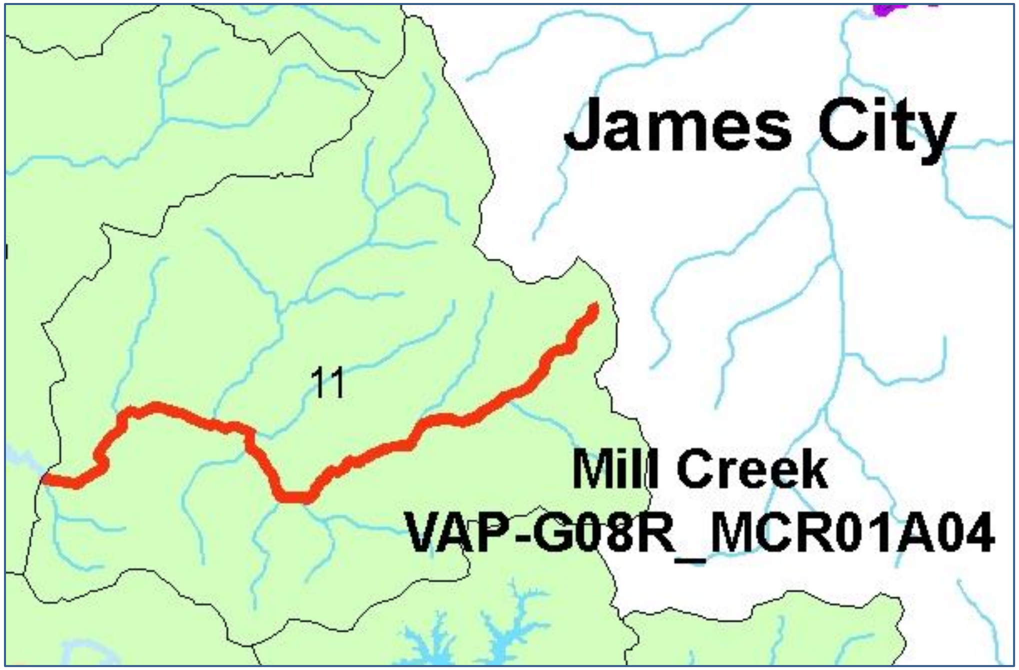
Impaired Water	Source	Percentage of Total Load
Beaverdam Creek (Subwatersheds 2, 3)	Wildlife	86.2%
	Livestock	0.0%
	Pets	5.6%
	Humans	8.2%
	Totals	100%

Impaired Water	Source	Percentage of Total Load
Beaverdam Creek, UT (Subwatershed 3)	Wildlife	87.8%
	Livestock	0.0%
	Pets	5.6%
	Humans	6.5%
	Totals	100%

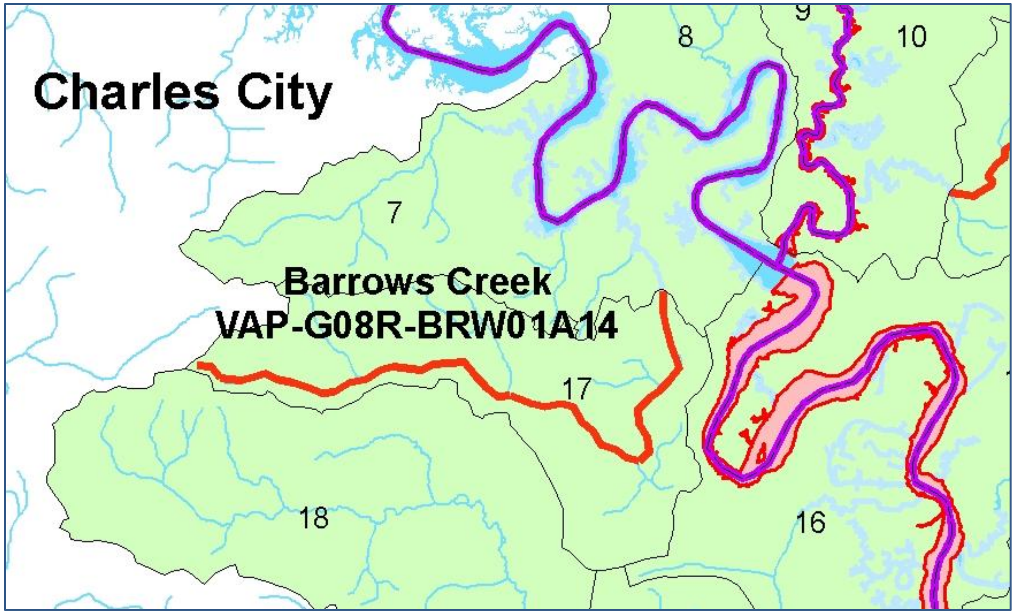


Impaired Water	Source	Percentage of Total Load
Mill Creek (Subwatershed 11)	Wildlife	52.2%
	Livestock*	39.0%
	Pets	1.4%
	Humans	7.3%
	Totals	100%

* Based on TAC feedback, these % load contributed are subject to change.

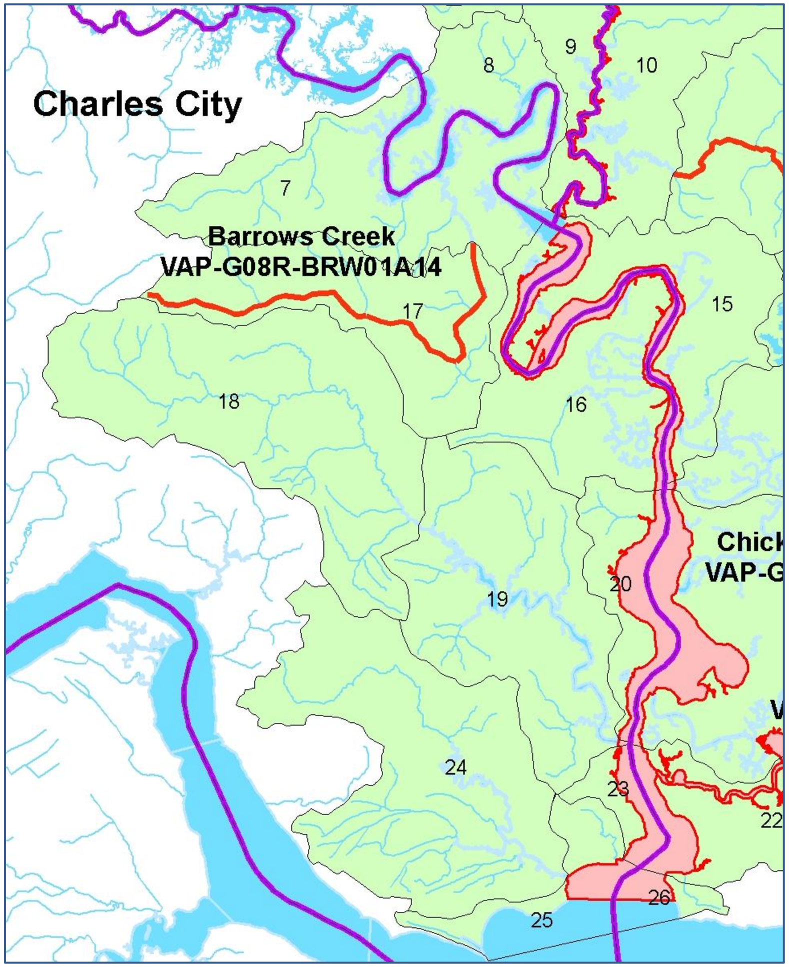


Impaired Water	Source	Percentage of Total Load
Barrows Creek (Subwatershed 17)	Wildlife	24.7%
	Livestock	55.4%
	Pets	0.9%
	Humans	18.8%
	Totals	100%



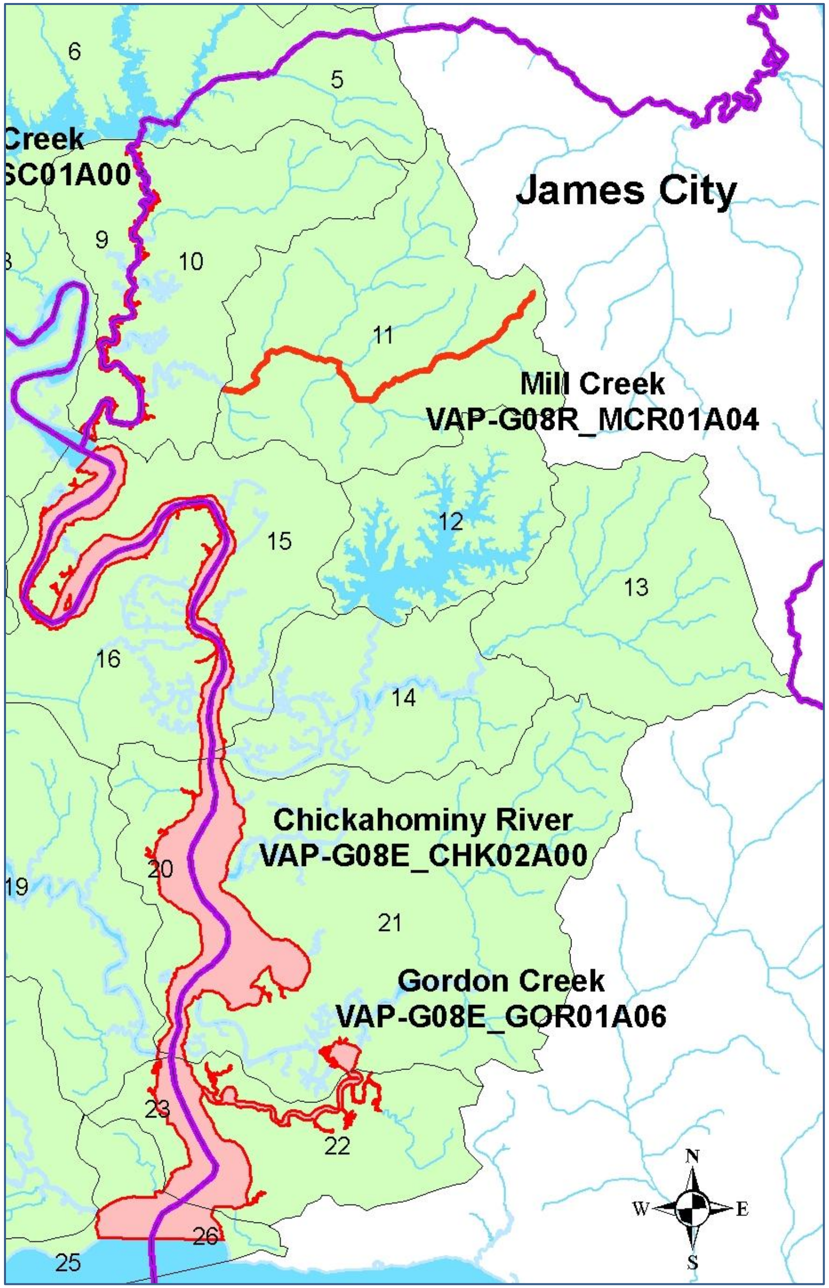
Source Assessment Summary --- by County*

Impaired Water	Source	Percentage of Total Load
Charles City (Subwatersheds 7, 16-20, 23-25)	Wildlife	51.9%
	Livestock	30.4%
	Pets	2.4%
	Humans	15.3%
	Totals	100%



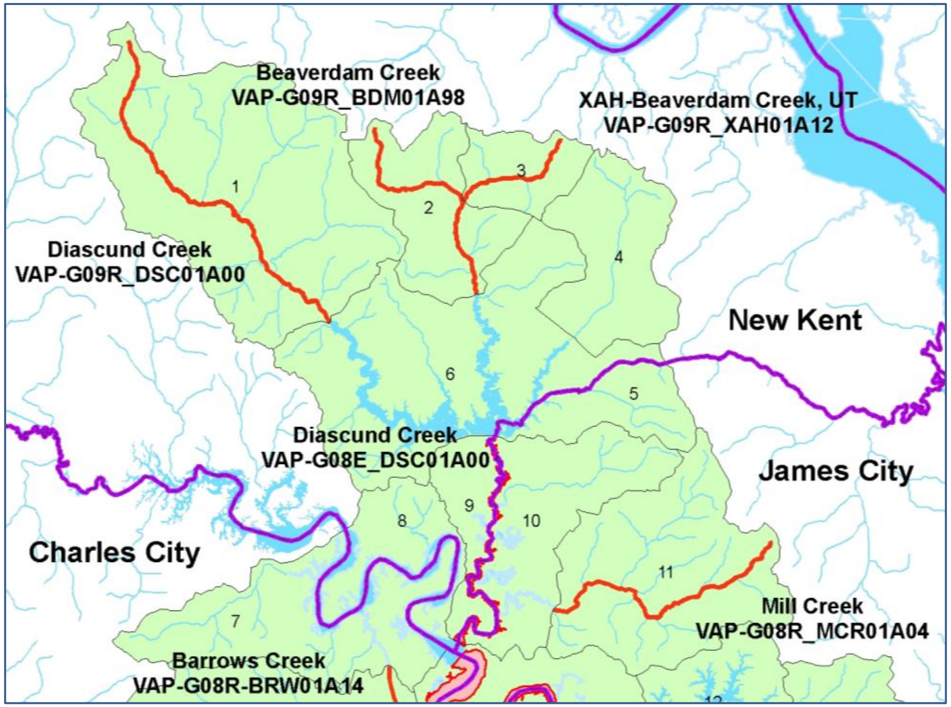
* Based on TAC feedback, these % load contributed are subject to change.

Impaired Water	Source	Percentage of Total Load
James City (Subwatersheds 5, 10-15, 21, 22, 26)	Wildlife	68.5%
	Livestock*	20.4%
	Pets	1.5%
	Humans	9.5%
	Totals	100%



* Based on TAC feedback, these % load contributed are subject to change.

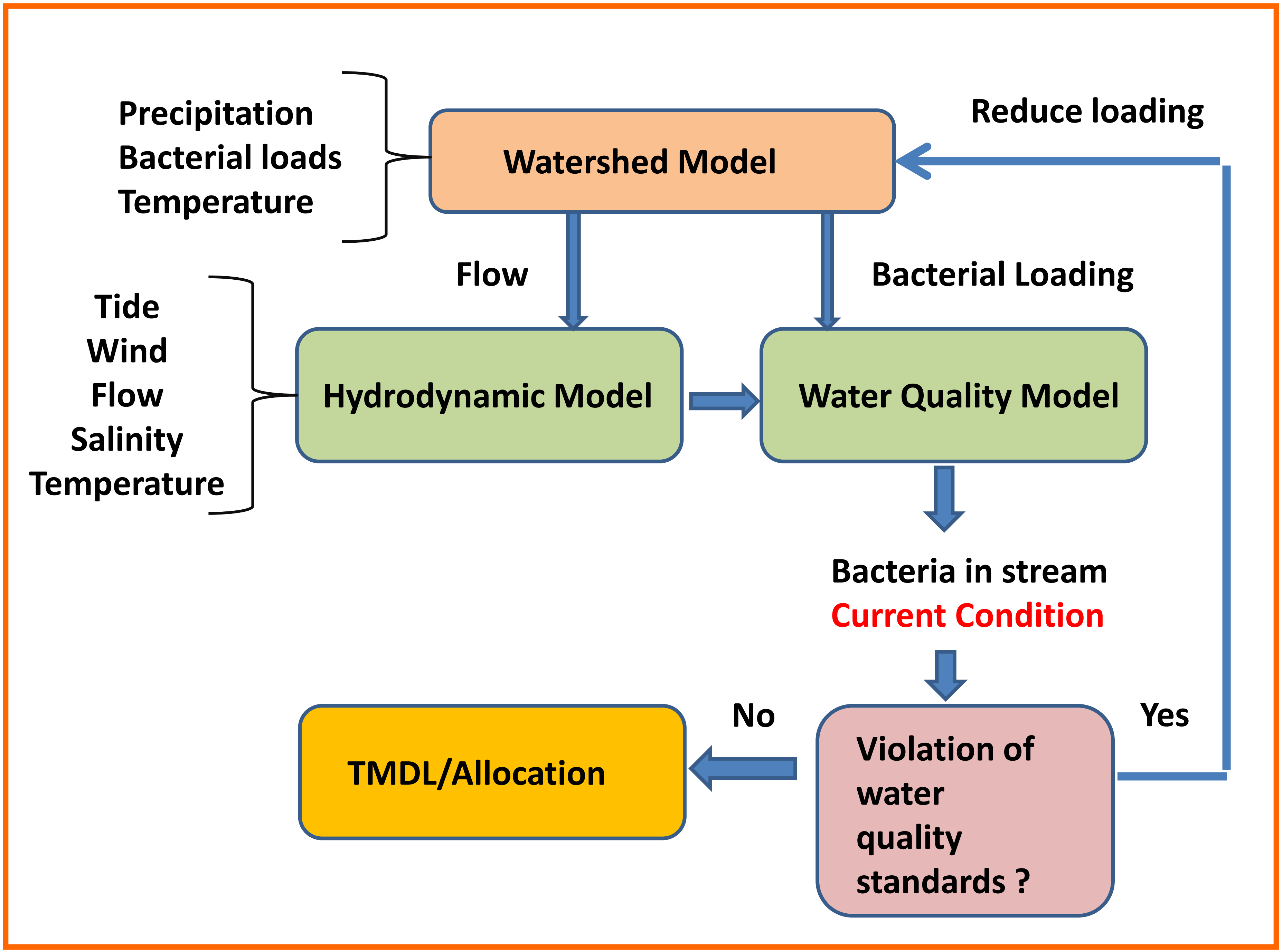
Impaired Water	Source	Percentage of Total Load
New Kent (Subwatersheds 1-4, 6, 8, 9)	Wildlife	82.7%
	Livestock	0.0%
	Pets	4.9%
	Humans	12.3%
	Totals	100%



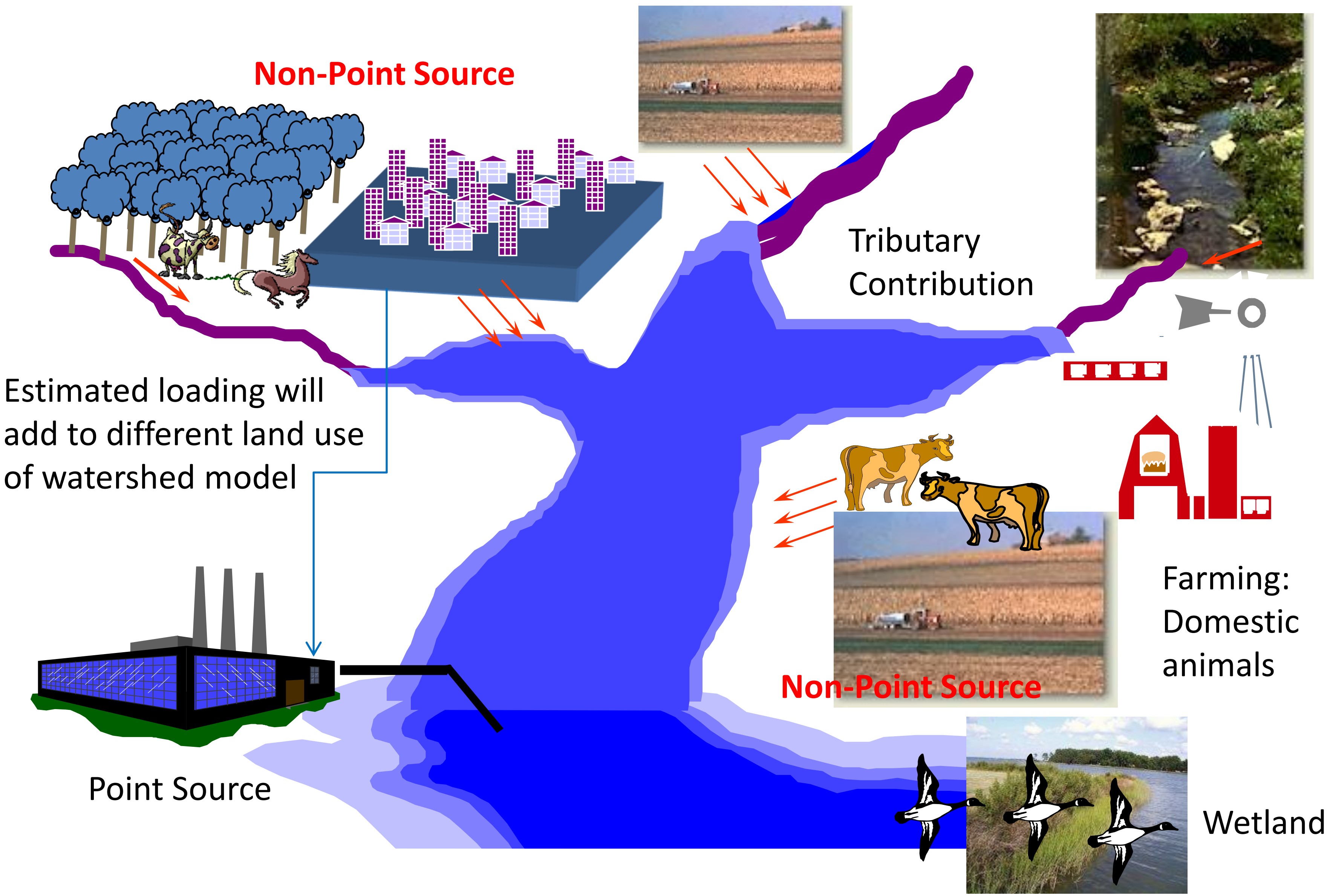
Modelling Approach

- Watershed Model
  - Use Loading Simulation Program C++ (LSPC) to simulate watershed processes - flow and bacteria

- Hydrodynamic-Water Quality Model
  - Use 3D hydrodynamic fluid environmental computation code (EFDC) to simulate instream processes - bacteria transport and fate


Precipitation
Bacterial loads
Temperature
Watershed Model
Reduce loading
Flow
Bacterial Loading
Tide
Wind
Flow
Salinity
Temperature
Hydrodynamic Model
Water Quality Model
Bacteria in stream
Current Condition
No
Yes
TMDL/Allocation
Violation of water quality standards ?

1. Watershed Model Development



LSPC Model Setup

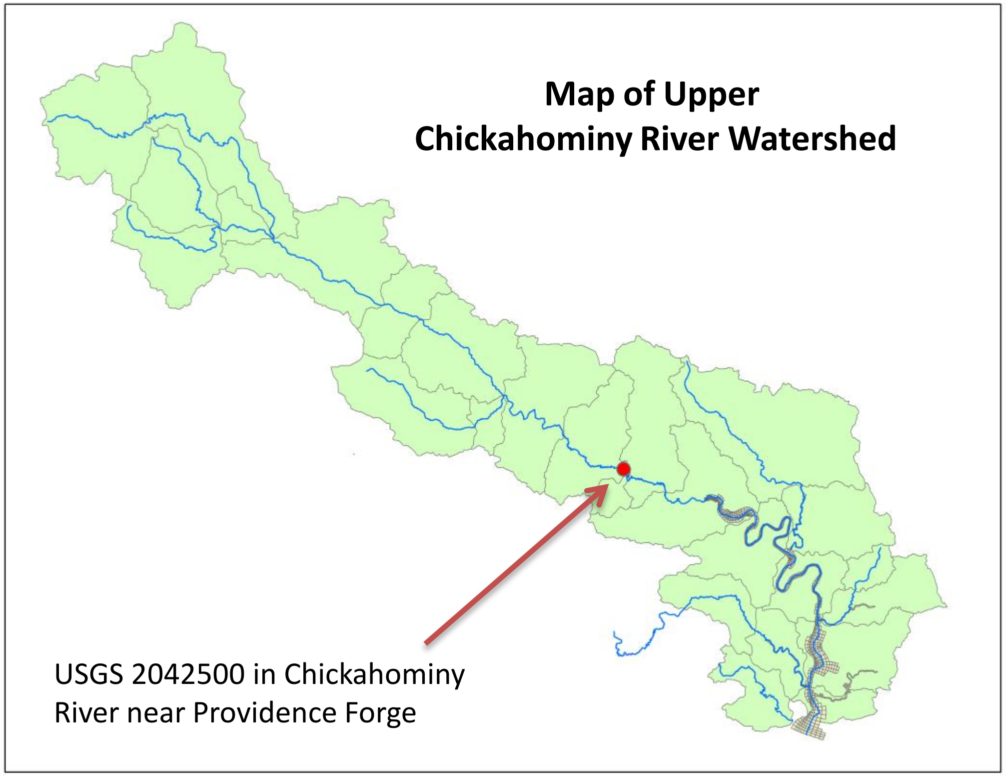
1. Use hourly precipitation to drive the model
2. Simulate loading and transport of bacterial for different landuses for each subwatershed- Urban pervious and impervious, wetland, forest, agricultural, past land (grass),barren, and other

Modeling Processes

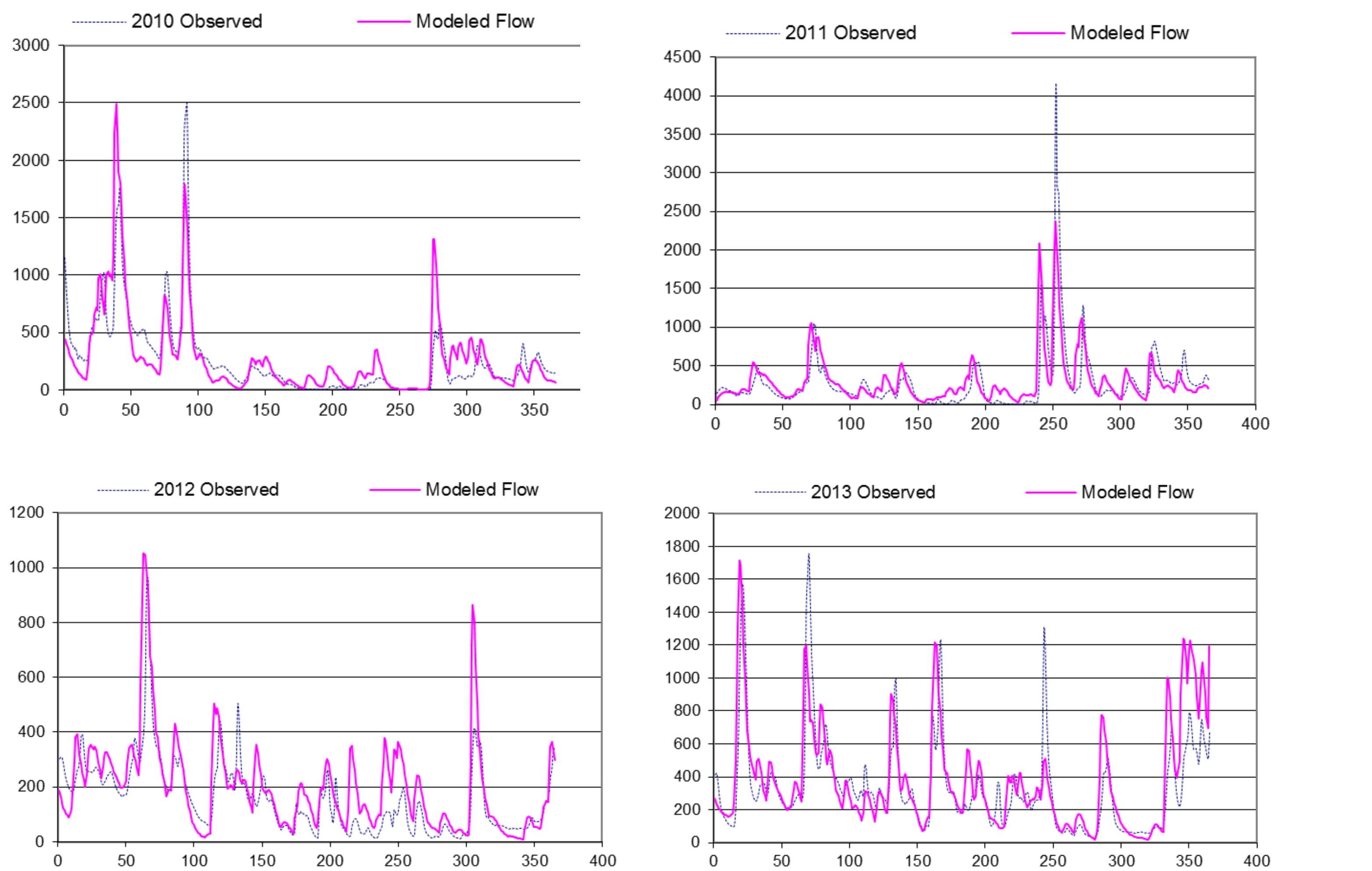
1. Calibrate model for flow
2. Input bacterial loading as count/ac/day based on source assessment
3. Simulate non-point source loading by each subwatershed
4. Conduct watershed model calibration using non-tidal instream observations
5. Provides daily flow and bacterial loading to hydrodynamic and water quality models

Flow Calibration

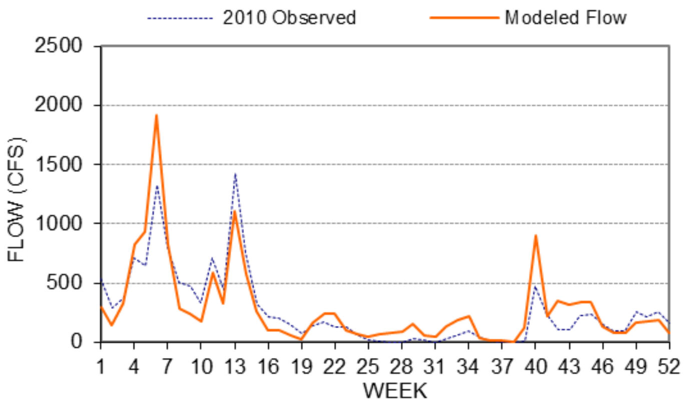
- There is no USGS gauge station in the watershed. The watershed model was calibrated for large Chickahominy watershed (upstream) where USGS long-term flow measurements are available.

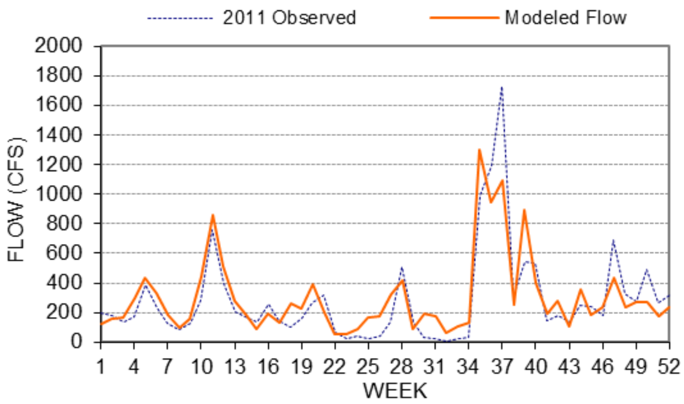


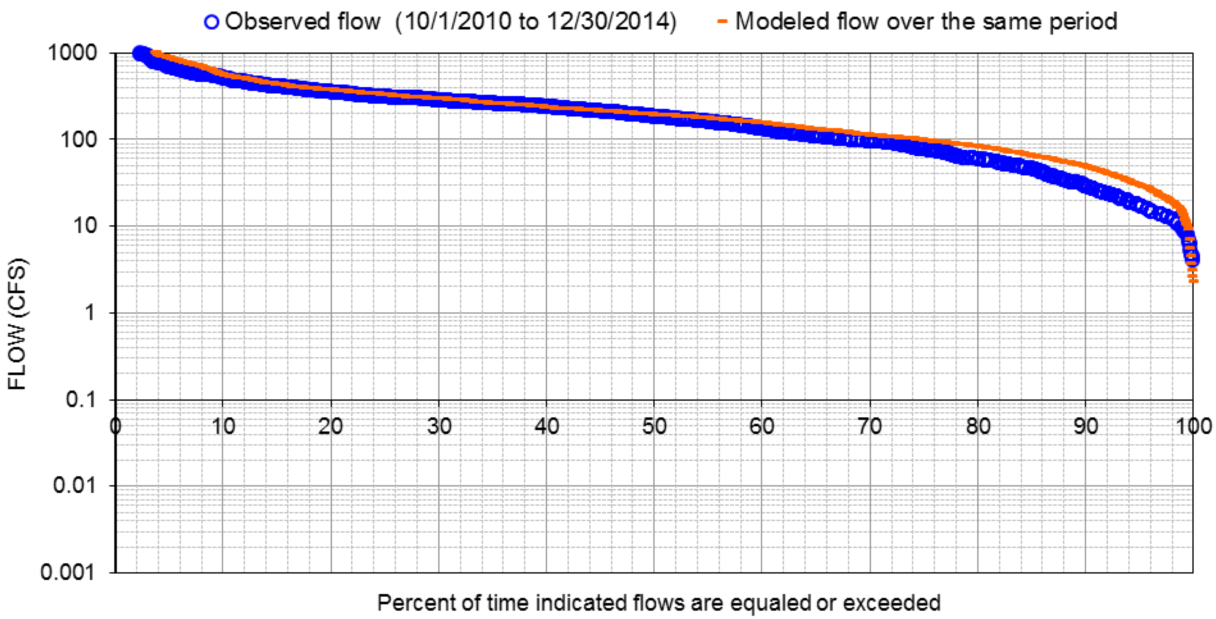
Hydrology Calibration Results



Hydrology Calibration Results





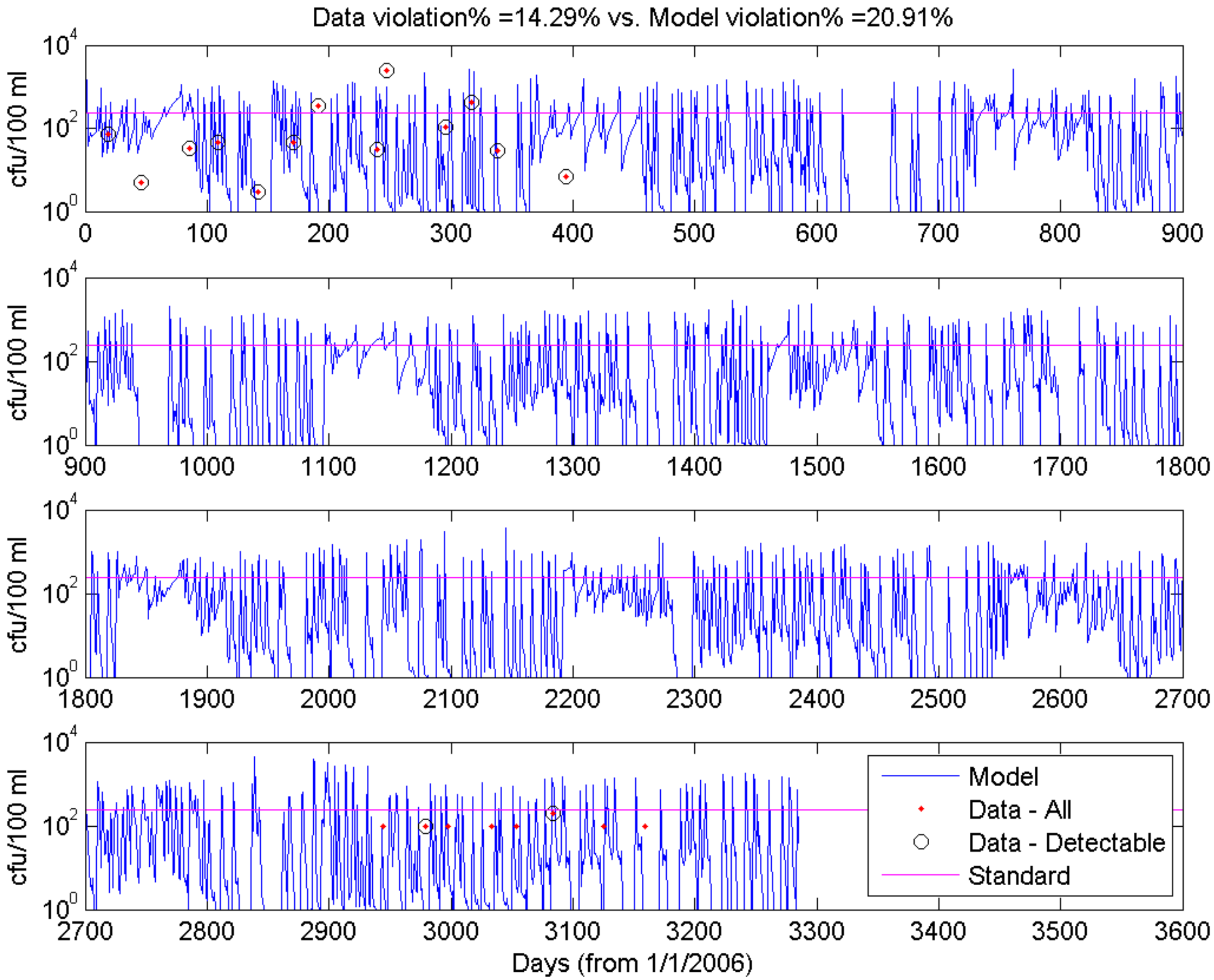


Calibration of Watershed Model for Bacterial Simulation

1. Whether the model result covers the observation range
2. Compare the violation rates of model results and observations
3. Criteria

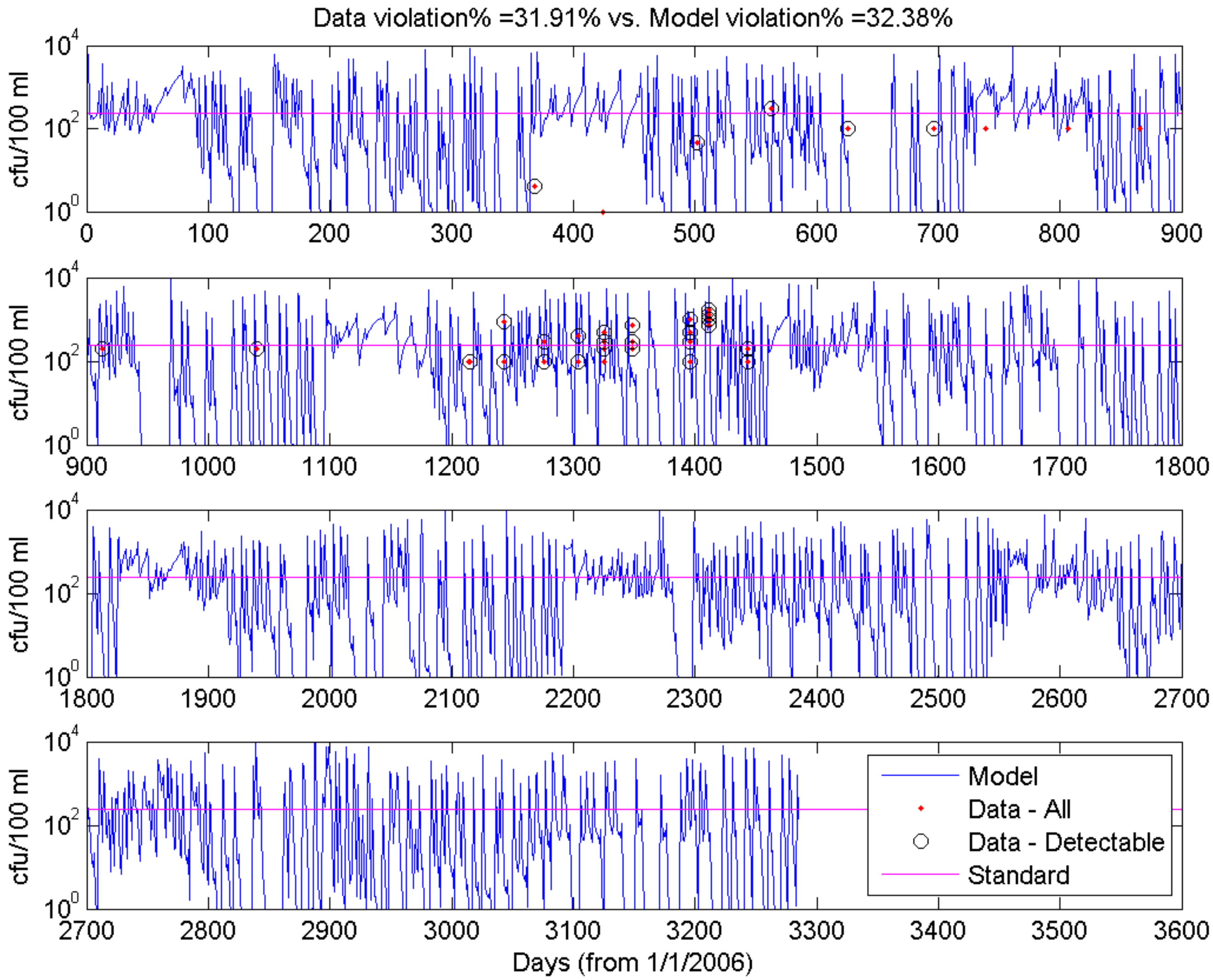
- 126 counts/100ml maximum and
- No more than 10% of the total samples in the assessment period shall exceed 235 counts/100 ml .

Preliminary Calibration Results of Diascund Creek (Nontidal)

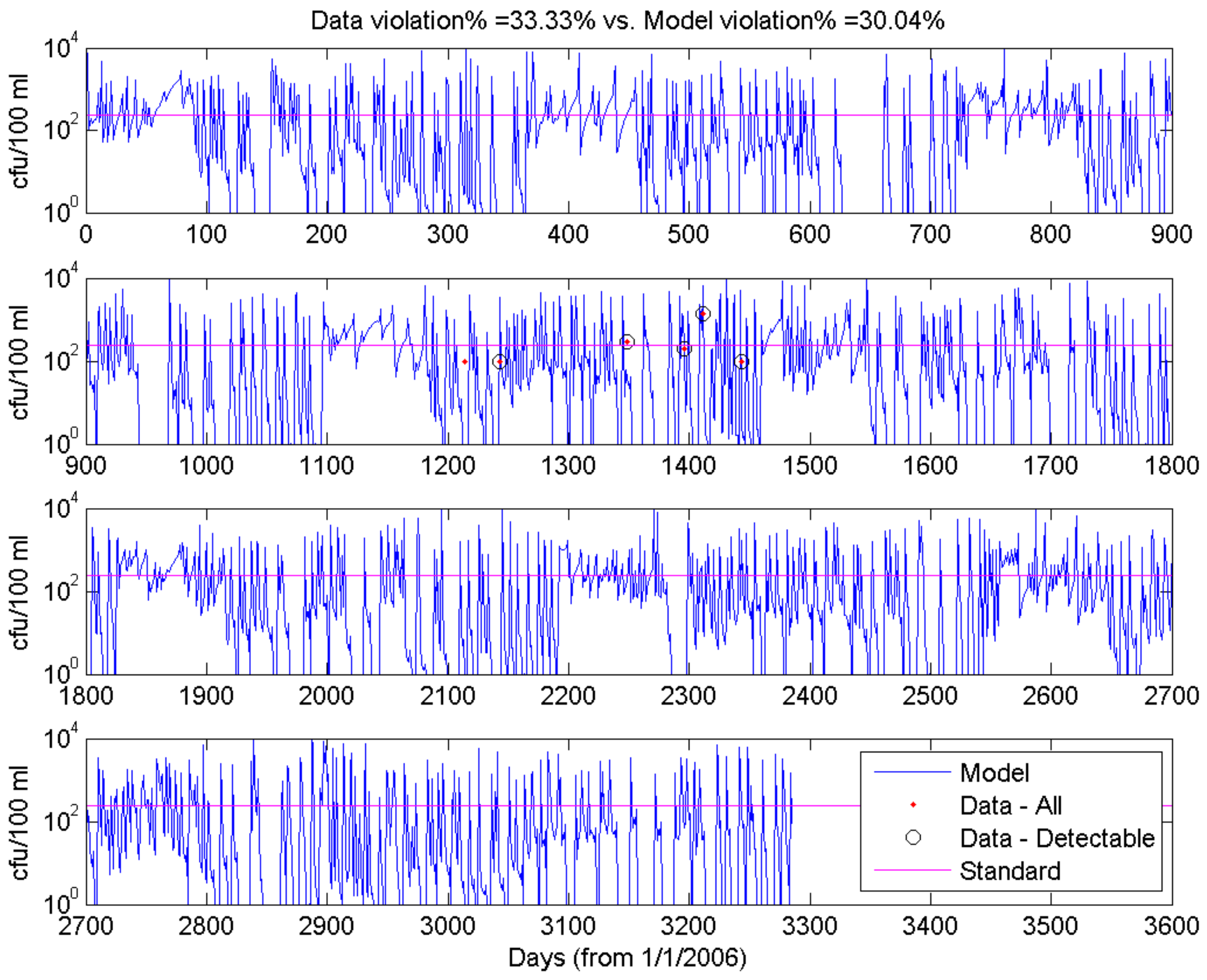


- **Data-All** means all the observations, including detectable and nondetectable data
- **Data-Detectable** means all the observations that are detectable

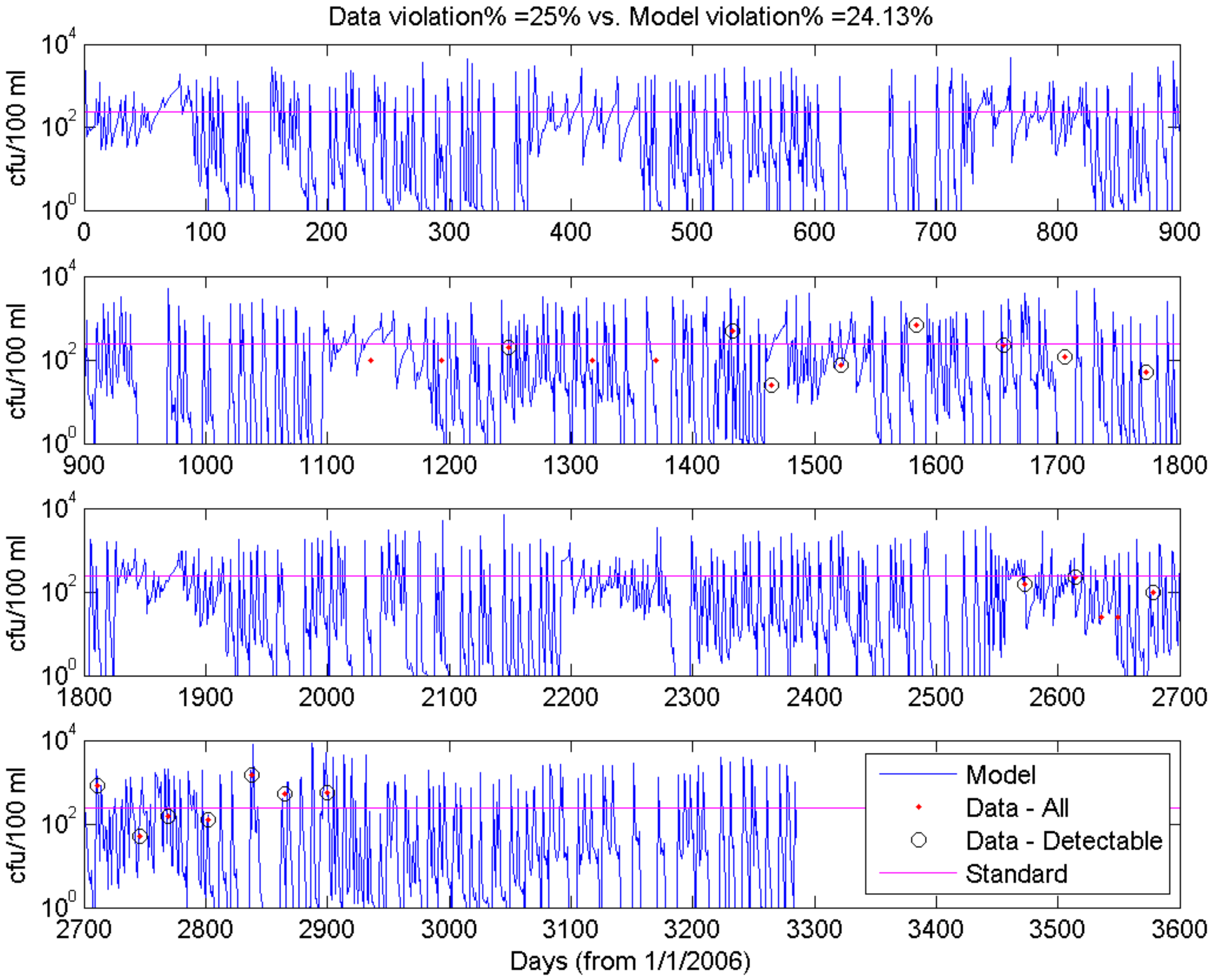
Preliminary Calibration Results Beaverdam Creek



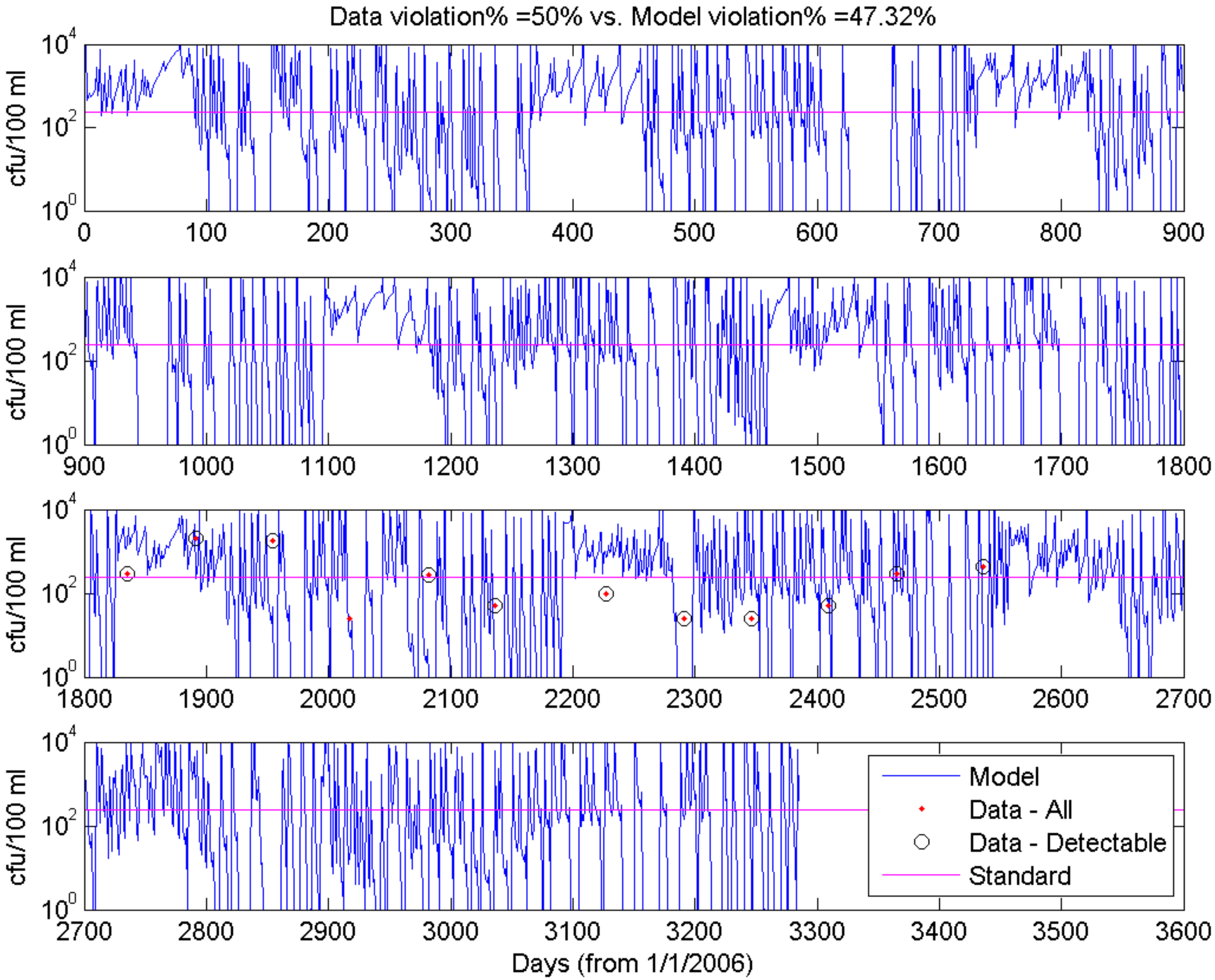
Preliminary Calibration Results of Beaverdam Creek, UT



Preliminary Calibration Results of Mill Creek



Preliminary Calibration Results of Barrows Creek

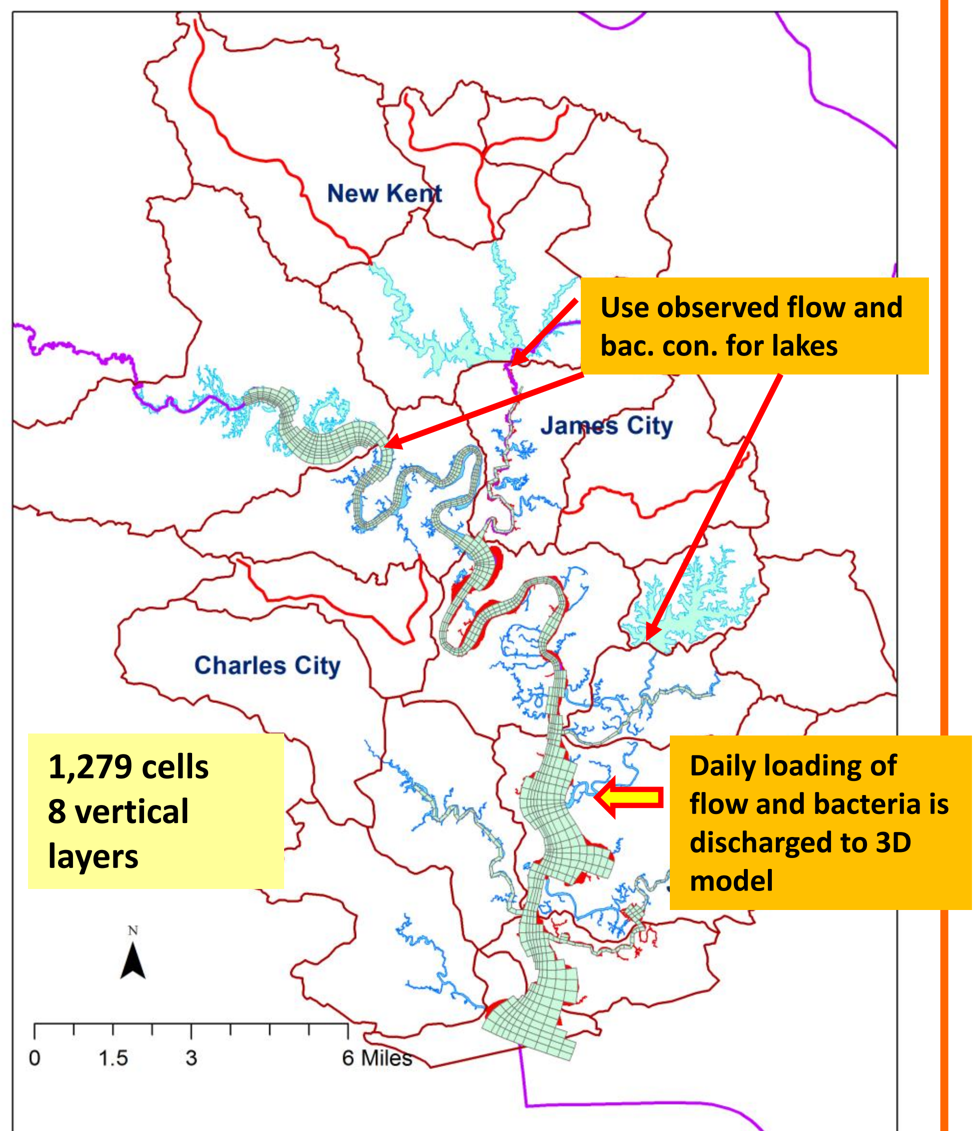


Summary of Watershed Model Calibration

- Model simulation of instream bacterial concentration is within the range of observations.
- Many sample observations are below the analytical detection limits – and assigned a value of (25/100), which are difficult to use. *(the actual lab result may have been lower)*
- Careful assessment of model results is needed to ensure that the model does not over-predict the bacterial concentration
- Next Step
  - Refine model calibration
  - Consider the variation of each watershed, the initial estimated loading (i.e., uniform distribution of wildlife for example) will be adjusted based on model calibration

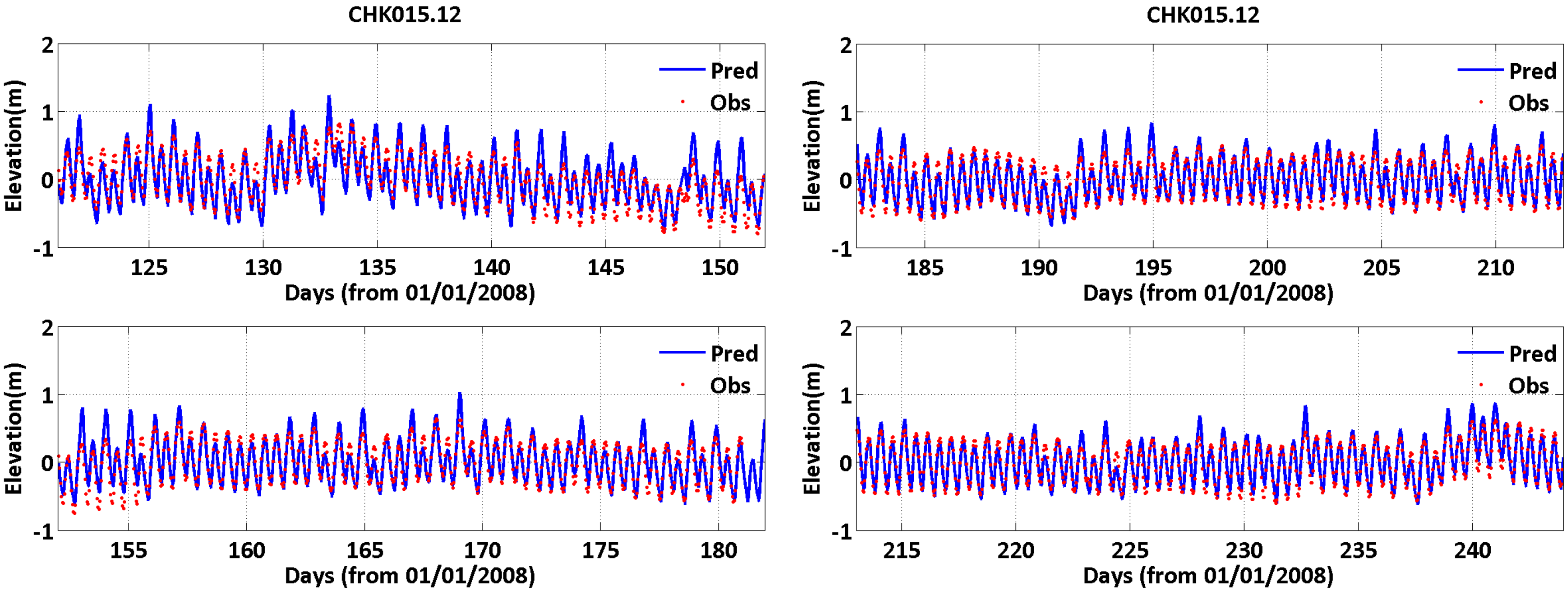
2. Hydrodynamic-Water Quality Model Development

- Use EFDC (Environmental Fluid Dynamics Code) to simulate flow and bacterial transport in estuary
- Open boundary condition is derived from output of hourly tide and salinity from the James River 3D model (DEQ algal project)
- Model calibration was conducted for dynamics (tide, salinity and bacterial concentration)

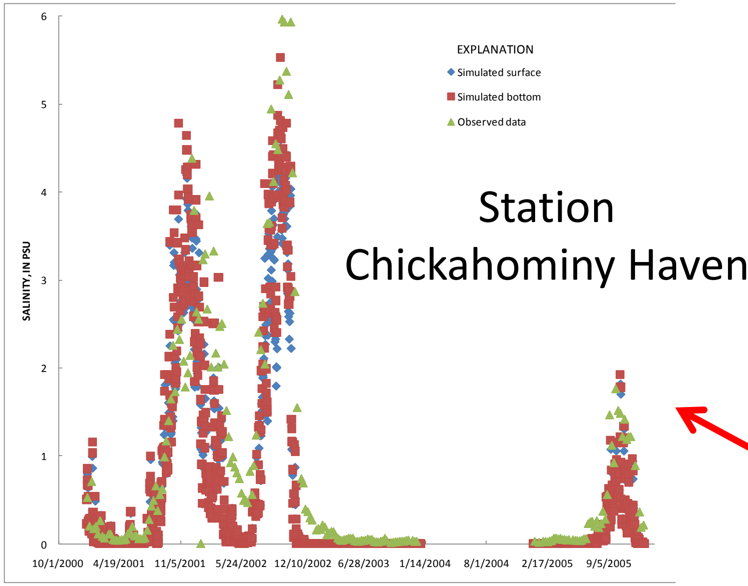


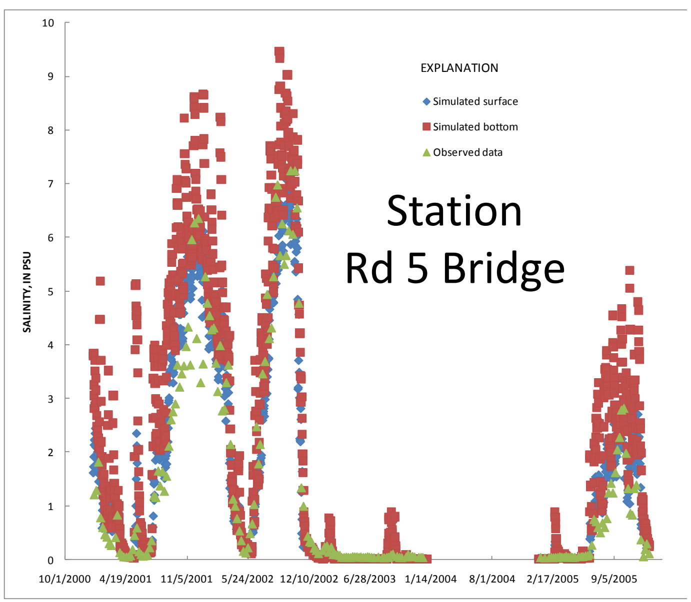
Hydrodynamic-Water Quality Model Calibration Result

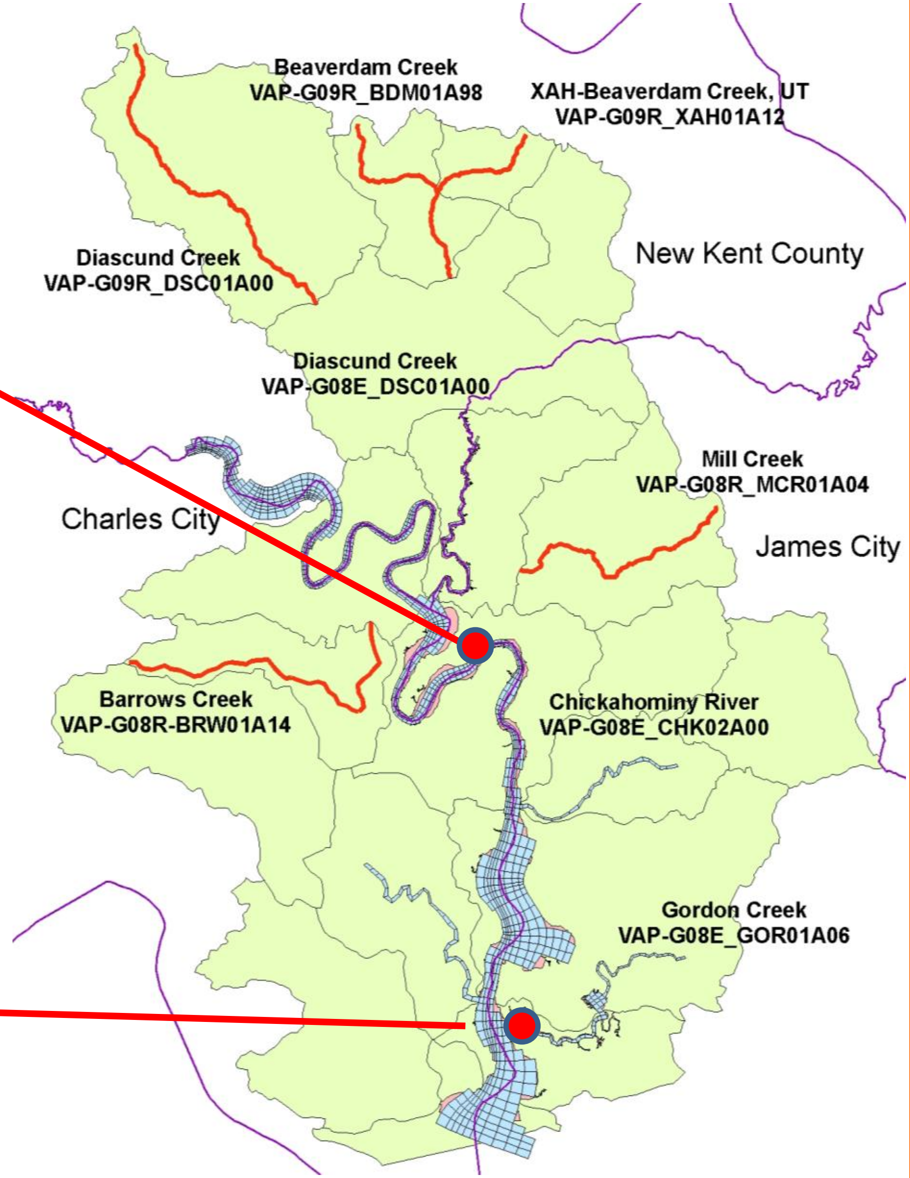
- Surface Elevation Calibration



• Salinity Calibration







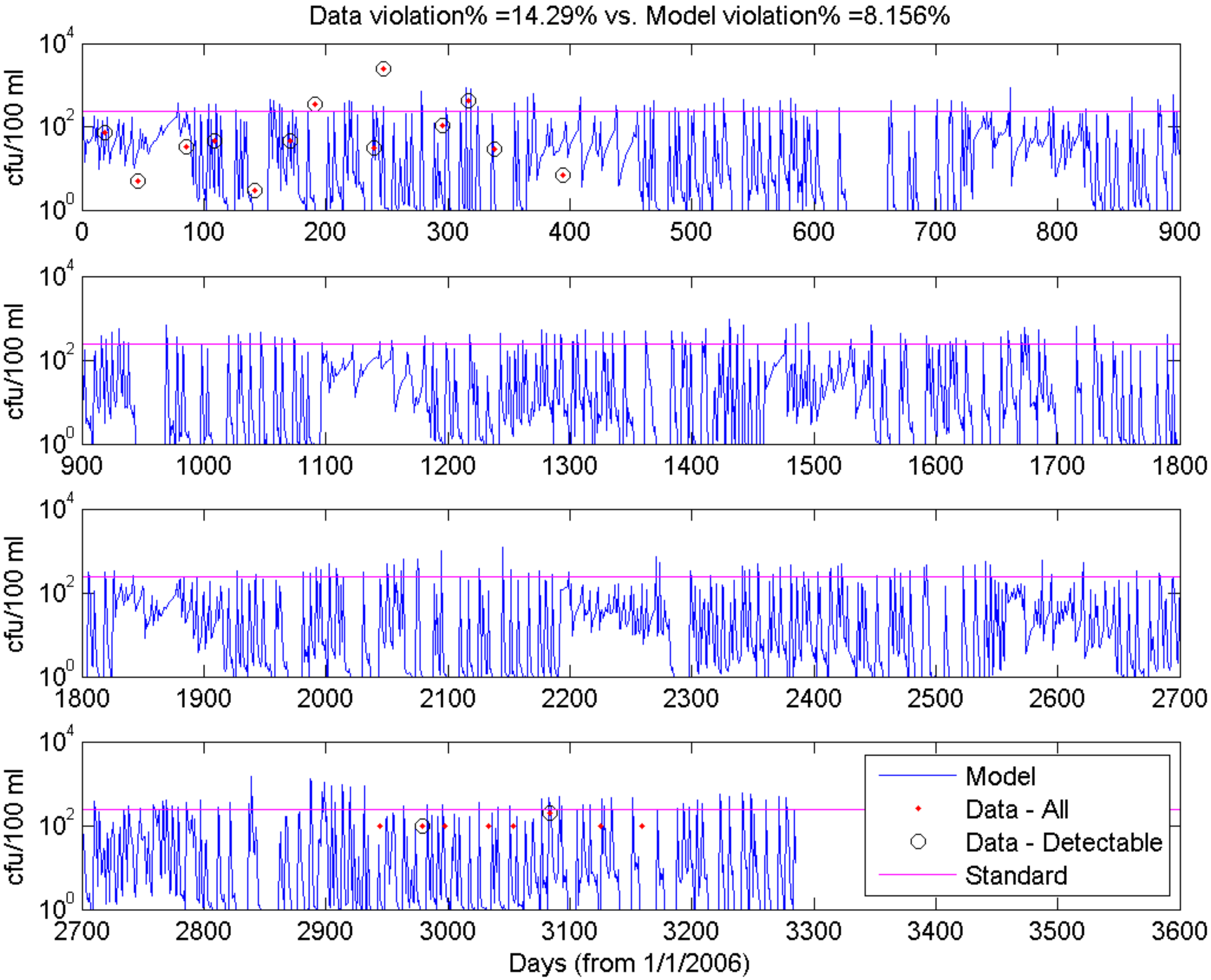
Bacterial Model Calibration

- Although the bacterial model calibration demonstrates that the watershed model estimation of loading in the upstream watershed is within the correct range, the estuary model simulation shows that we under-estimate the loading from adjacent watersheds
- The possible cause of the problem
  - There are unknown sources within the watershed
  - The wildlife on marsh and wetland are more active
  - The tide can wash off bacterial loading from land
  - SSO, boating, and point sources (straight pipes)
- We will continue to investigate the problem and conduct model calibration

TMDL Development

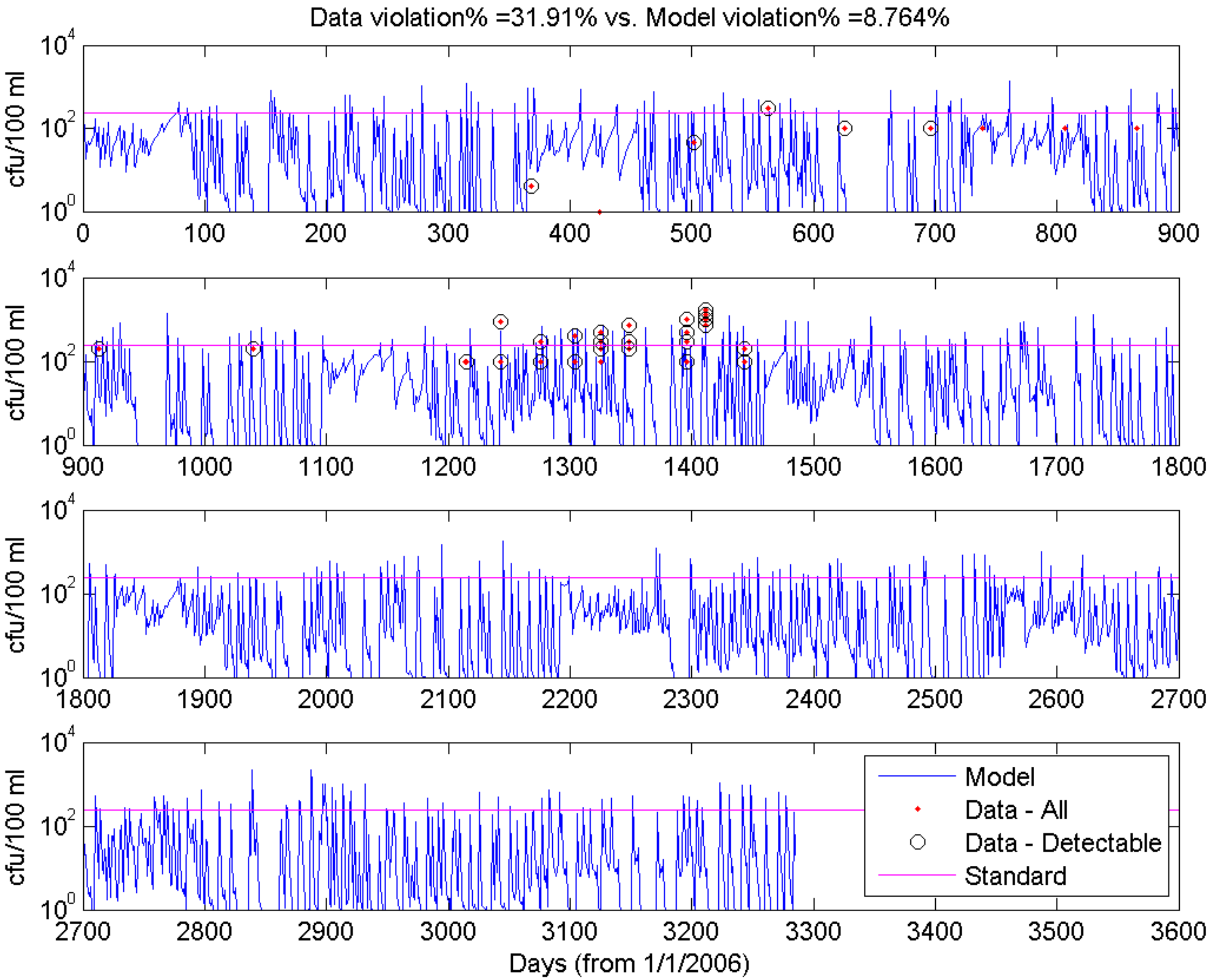
Loads from the watershed were reduced so that the water quality standards are met in the receiving water 9i.e., so that the violation becomes less that 10%).

TMDL Results of Diascund Creek (Nontidal)

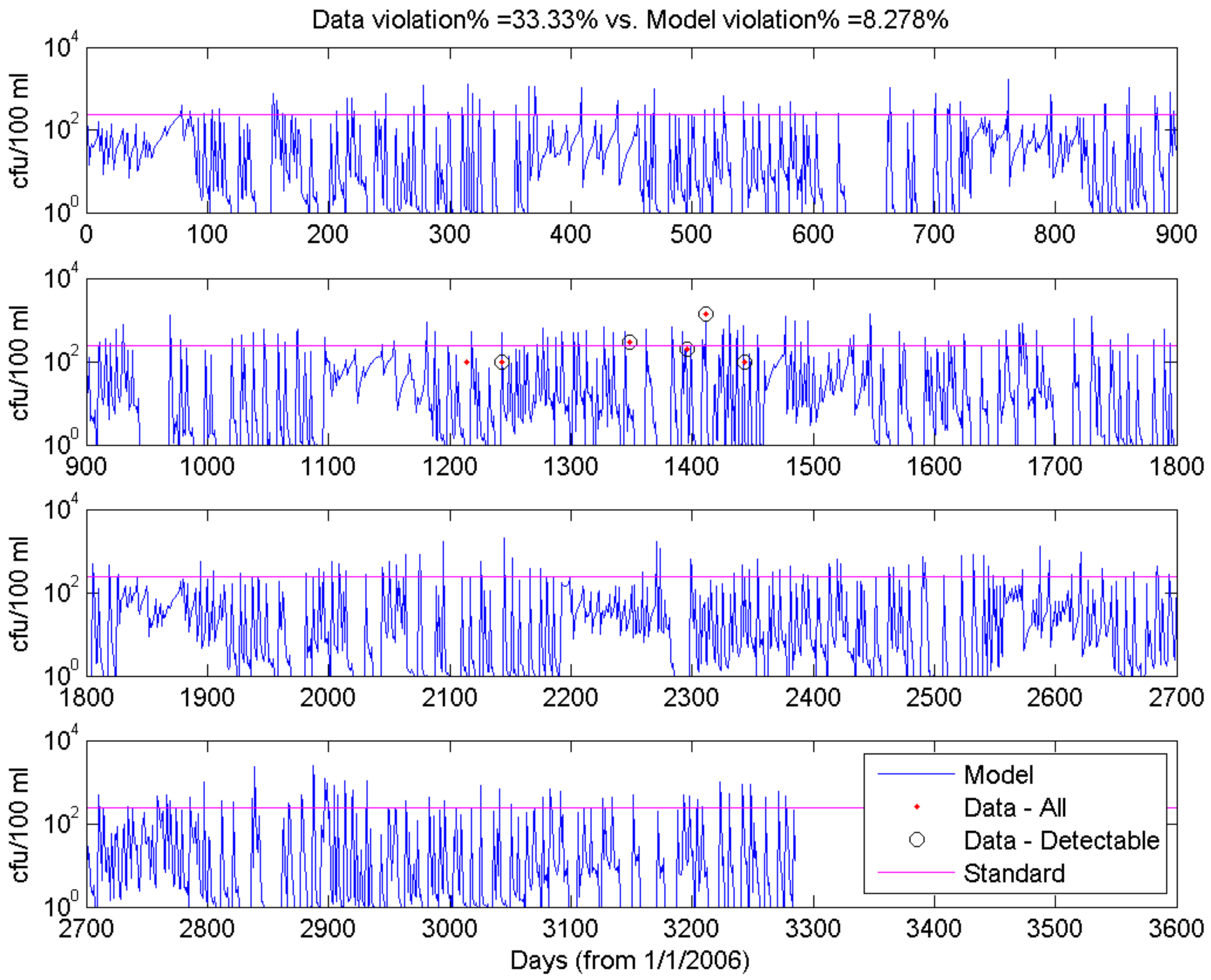


- **Data-All** means all the observations, including detectable and nondetectable data
- **Data-Detectable** means all the observations that are detectable

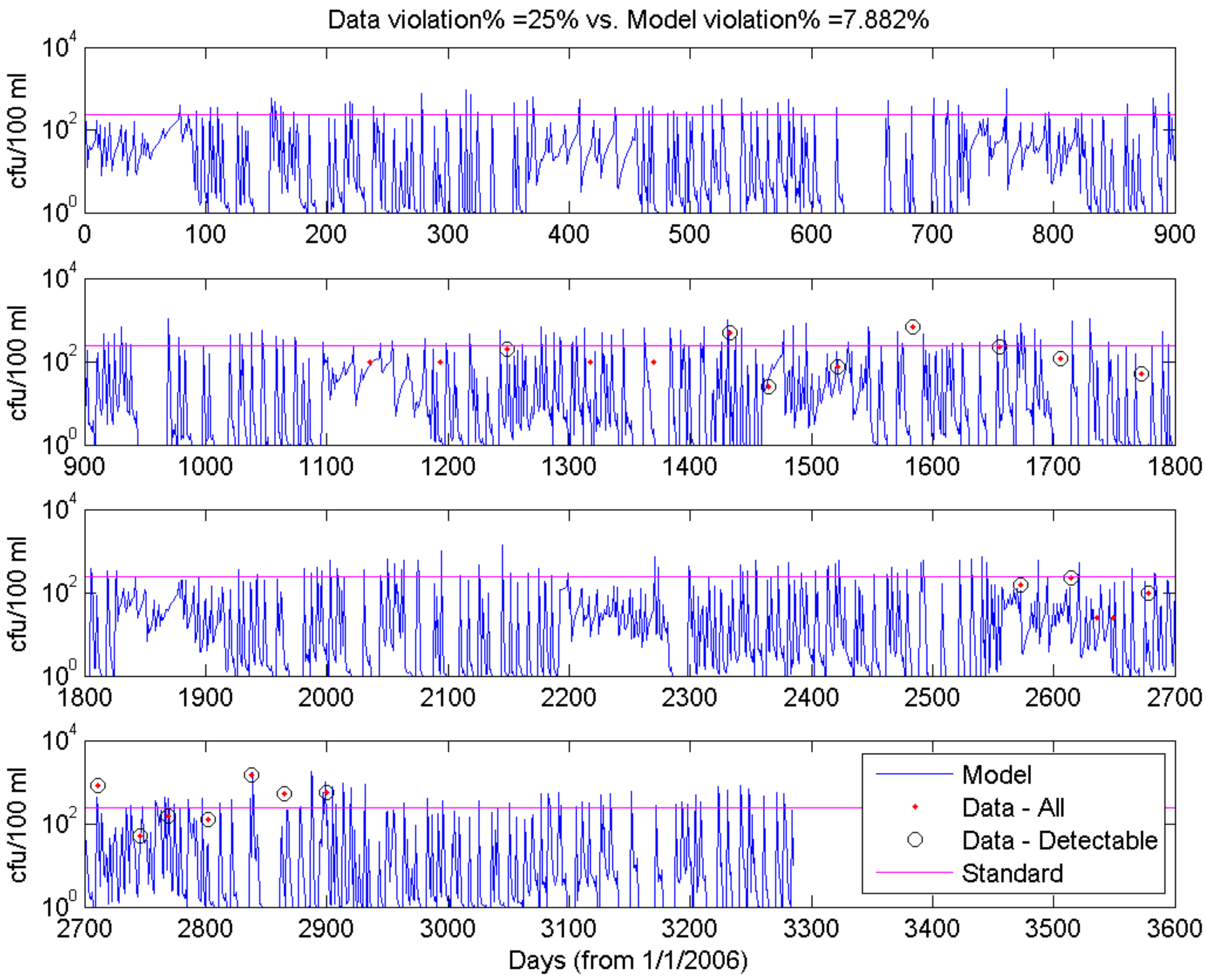
TMDL Results Beaverdam Creek



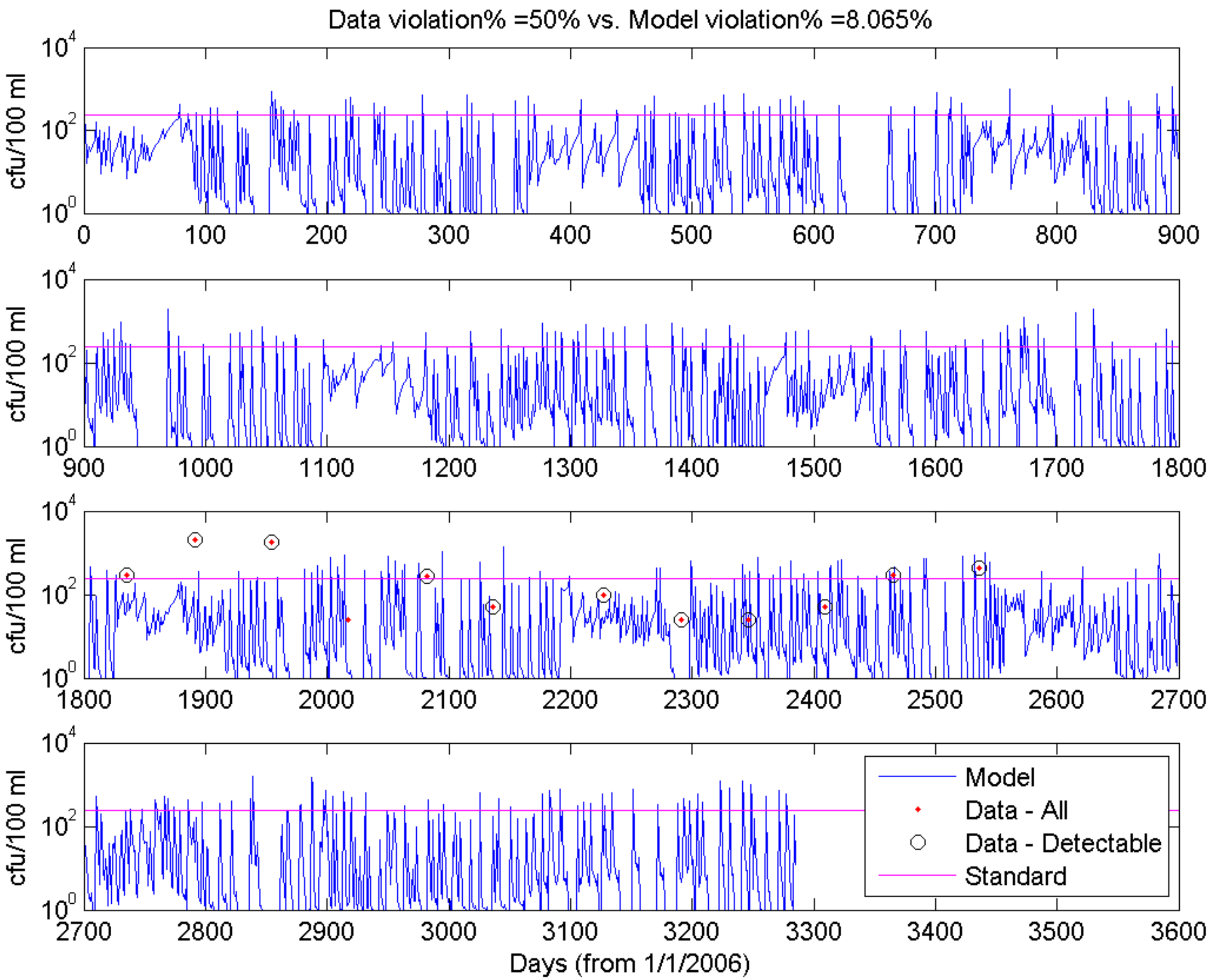
TMDL Results of Beaverdam Creek, UT



TMDL Results of Mill Creek



TMDL Results of Barrows Creek



Estimation of 90th Percentile Loading Based on Long-term Model Simulations

- Using long-term mean daily loads simulated by daily variation model will under estimate the maximum daily loads
- Following USEPA guideline to convert long-term mean loading to 95th percentile maximum daily load
  - **The maximum daily load is a value that will be exceeded with a pre-defined probability:** In this option, a "reasonable" upper bound percentile is selected for the maximum daily load based upon a characterization of the variability of daily loads. For example, selection of the 95th percentile value would result in a maximum daily load that would be exceeded 5% of the time.

Estimation of 95th Percentile Loading Based on Long-term Model Simulations

$$TMDL = LTA \cdot \exp(Z_p \sigma_y - 0.5\sigma_y^2)$$

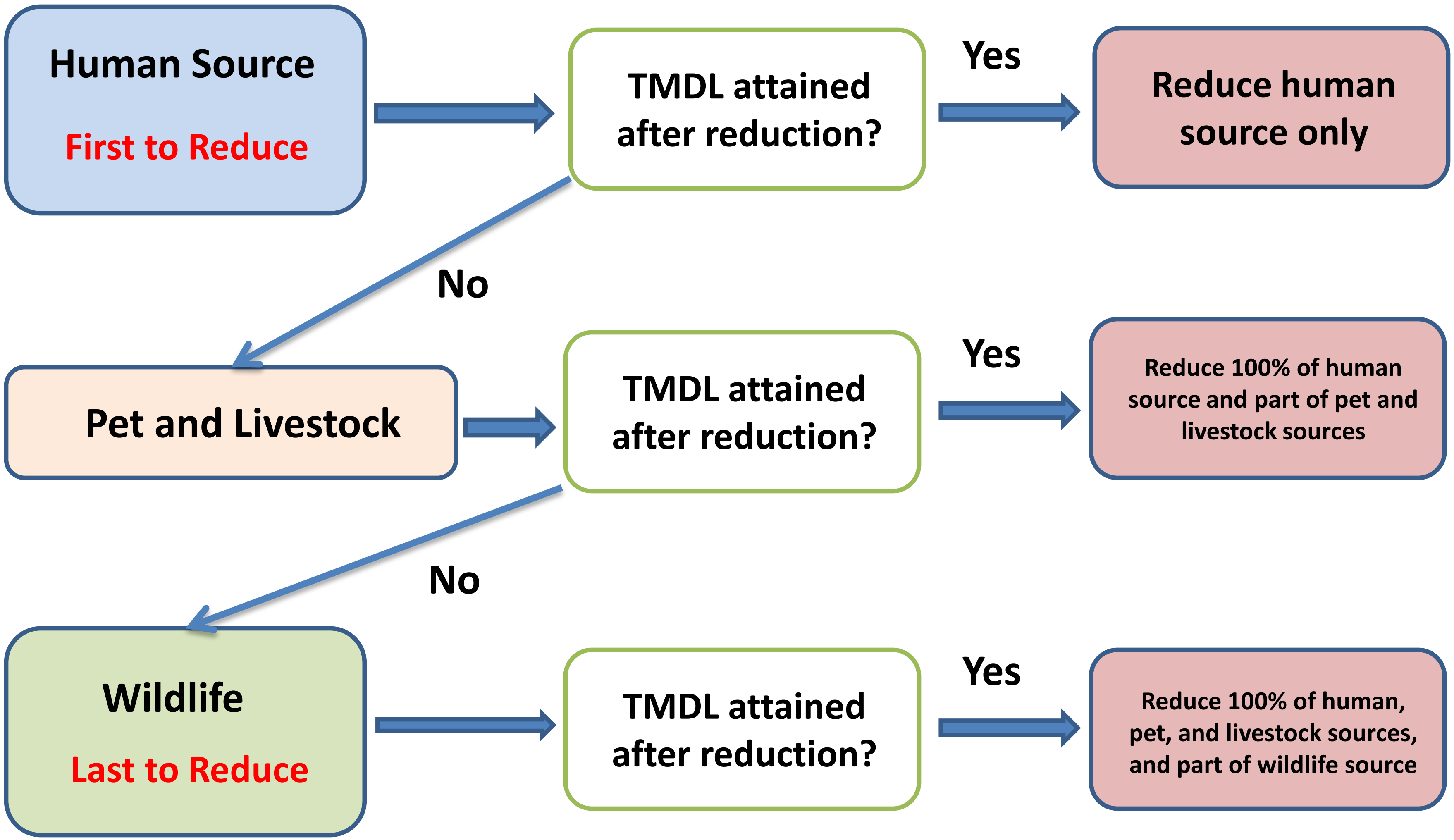
Where Zp is pth percentage point of the standard normal distribution. For the 95th percentile, Zp = 1.645 (for the 90th percentile, Zp = 1.28). LTA is long-term mean daily loading and σ_y is computed as:

$$\sigma_y = \sqrt{\ln(CV^2 + 1)}$$

where the CV is coefficient of variation of the untransformed data, which equals the standard deviation divided by the mean.

USEPA 2007

Principle for Load Reduction



Preliminary Results of Load Reduction and Allocation
*(Non-tidal segments)**
Diascund Creek (Nontidal)

Diascund Creek (Nontidal)	Existing E.Coli Load (Count/Day)	TMDL** (Count/Day)	% Reduction
Wildlife	1.8E+11	6.7E+10	62.6%
Livestock	0.0E+00	0.0E+00	NA
Pet	1.3E+10	0.0E+00	100.0%
Septic Failures	7.2E+09	0.0E+00	100.0%
Boating	8.6E+07	0.0E+00	100.0%
Straight Pipe	3.7E+09	0.0E+00	100.0%
Biosolids	0.0E+00	0.0E+00	NA
SSO	0.0E+00	0.0E+00	NA
TOTAL	2.0E+11	6.7E+10	67.1%

* Based on TAC feedback, these % load contributed are subject to change.

** Without statistical correction

Beaverdam Creek, UT

Beaverdam Creek, UT	Existing E.Coli Load (Count/Day)	TMDL (Count/Day)	% Reduction
Wildlife	7.6E+10	1.2E+10	84.6%
Livestock	0.0E+00	0.0E+00	NA
Pet	4.9E+09	0.0E+00	100.0%
Septic Failures	1.5E+09	0.0E+00	100.0%
Boating	2.8E+07	0.0E+00	100.0%
Straight Pipe	8.0E+08	0.0E+00	100.0%
Biosolids	0.0E+00	0.0E+00	NA
SSO	0.0E+00	0.0E+00	NA
TOTAL	8.4E+10	1.2E+10	86.0%

Beaverdam Creek

Beaverdam Creek	Existing E.Coli Load (Count/Day)	TMDL (Count/Day)	% Reduction
Wildlife	3.0E+11	4.5E+10	84.7%
Livestock	0.0E+00	0.0E+00	NA
Pet	1.9E+10	0.0E+00	100.0%
Septic Failures	1.2E+10	0.0E+00	100.0%
Boating	5.6E+07	0.0E+00	100.0%
Straight Pipe	6.2E+09	0.0E+00	100.0%
Biosolids	0.0E+00	0.0E+00	NA
SSO	0.0E+00	0.0E+00	NA
TOTAL	3.3E+11	4.5E+10	86.5%

Mill Creek

Mill Creek	Existing E.Coli Load (Count/Day)	TMDL (Count/Day)	% Reduction
Wildlife	1.5E+11	3.5E+10	75.8%
Livestock	7.0E+08	0.0E+00	NA
Pet	4.0E+09	0.0E+00	100.0%
Septic Failures	1.3E+10	0.0E+00	100.0%
Boating	1.4E+08	0.0E+00	100.0%
Straight Pipe	6.9E+09	0.0E+00	100.0%
Biosolids	0.0E+00	0.0E+00	NA
SSO	0.0E+00	0.0E+00	NA
TOTAL	1.7E+11	3.5E+10	79.4%

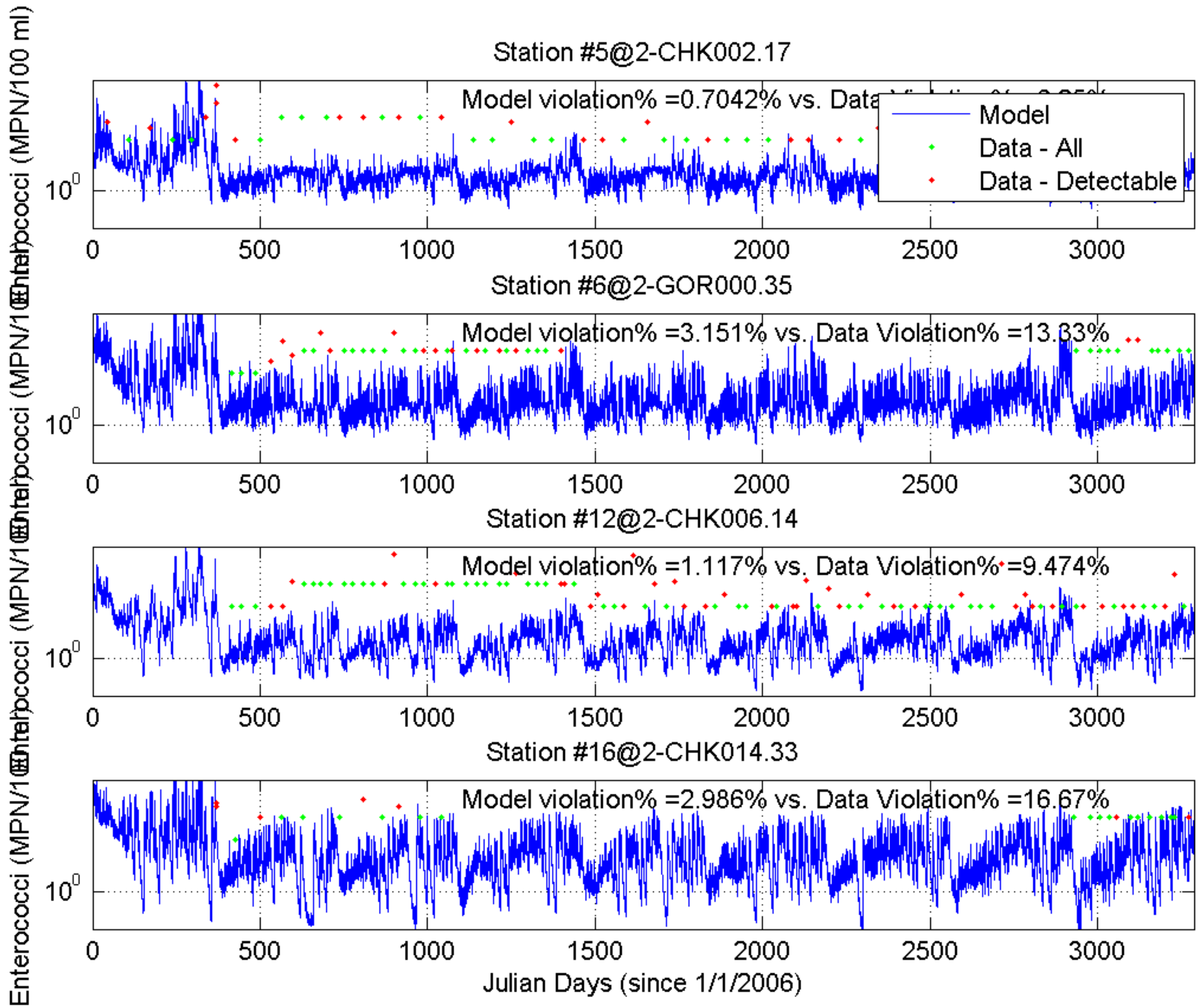
Barrows Creek

Barrows Creek	Existing E.Coli Load (Count/Day)	TMDL (Count/Day)	% Reduction
Wildlife	5.6E+11	1.8E+10	96.8%
Livestock	2.7E+09	0.0E+00	NA
Pet	1.5E+10	0.0E+00	100.0%
Septic Failures	5.2E+10	0.0E+00	100.0%
Boating	5.4E+08	0.0E+00	100.0%
Straight Pipe	2.7E+10	0.0E+00	100.0%
Biosolids	0.0E+00	0.0E+00	NA
SSO	0.0E+00	0.0E+00	NA
TOTAL	6.6E+11	1.8E+10	97.3%

Model Calibration for Tidal Segments

- Some difficulty is encountered for the model calibration for the tidal segment
- Problems with the model calibration for tidal segments include:
  - Loading is not high enough when one converts fecal coliform to Enterococci
  - Open boundary condition
  - Observation data for model calibration

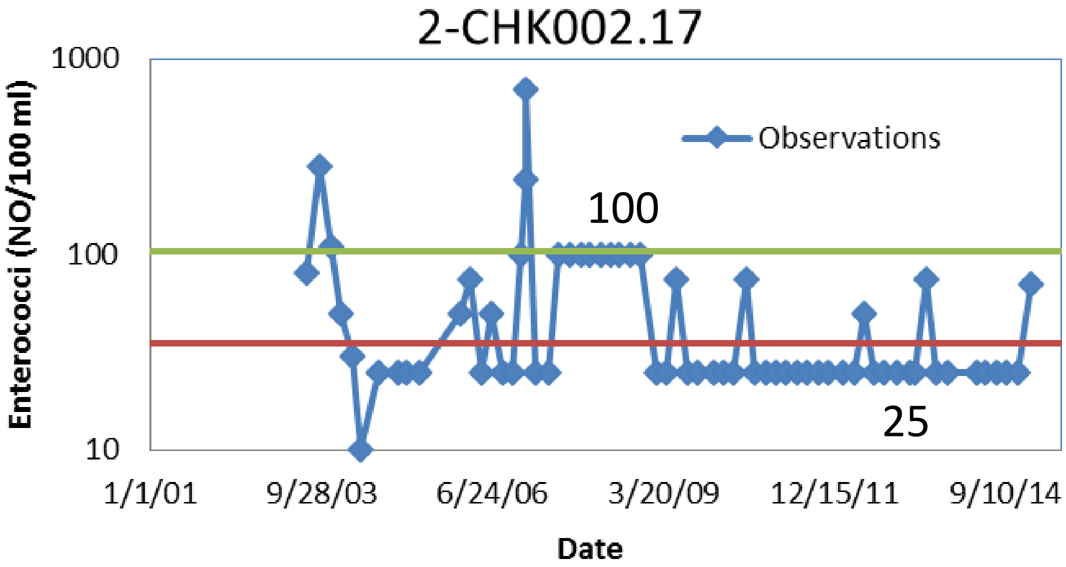
Example of Model Calibration*

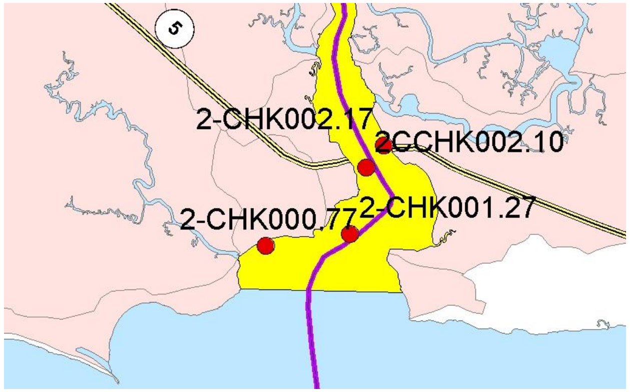


* Use boundary condition 10 cfu/100ml, and increase loading by 8 times

Uncertainty of the Open Boundary Condition

- Fecal coliform conc. Values near the mouth are 100 cfu/100ml (under detection limit) during 2002, which is about 37 cfu/100ml Enterococci.
- Enterococci observations have values of 100 cfu/100ml (under detection limit) during 2008-2009.
- The first station near the mouth with values of 25 and 100 cfu/100 ml are marked as “detection limit”, suggesting that boundary values can be between 25-100.





Available Data for Modeling Calibration

- Limited data available for model calibration are a part of the issue.

- The accuracy of measurement is also problematic and is likely contributing to the calibration issue. When measured values of bacteria are reported at a detection limit of 100 cfu/100ml, it becomes difficult for model calibration as the water quality standard is 104 cfu/100ml (Single Sample Maximum). Actual values may be much lower than “100”, for example.

How to Solve the Problem ?

- Current watershed loading is estimated based on fecal coliform.
  - Do not convert loading of fecal coliform to *Enterococci.* Directly simulate *Enterococci* loading using watershed model. Since all loading parameters are measured based on fecal coliform, calibrate the loading based on observations of *Enterococci.*
- Collect additional measurements at the mouth to remove the uncertainly of the contribution from outside.
  - How many?
- Current fecal coliform uses the mTEC method, which provides a more accurate measure of fecal coliform and is relatively easy to measure.
  - It can use fecal coliform to calibrate the model and convert model results to bacteria.

Calculation for Urban and MS4

- **Option 1**: Allocate MS4 loading based on partition of urban landuse and non-urban landuse (as defined by NLCD 2011) within the regulated MS4 area (area GIS layers are provided by James City County and VDOT) based on landuse data. This approach depends on reliability of landuse data used for computing the partition.

- **Option 2**: Allocate loading within regulated MS4 area (area GIS layers are provided by James City County and VDOT) to MS4. Because the dominant landuse within the MS4 area is urban landuse, it is reasonable to allocate *all* loading to MS4

Example MS4 WLA calculation for Option 1

- Total TMDL: 17,021,276.6 # per day (modeled)
- Future allocation (1% of TMDL) = 170,212.7 # per day
- MOS (5% of TMDL) = 851,063.8 # per day
- Total Loadings for allocation = 1,600,000 # per day
- Loading from urban land = 10,000,000 # per day
- Loading from nonurban land = 6,000,000 #per day
- Total area = 100 ac
- Urban landuse = 50 ac
- Nonurban landuse = 50 ac
- MS4 regulated area = 30 ac
- Urban landuse within MS4 regulated area is 90% of the total regulated area
- Urban landuse within MS4 regulated area = 90% x 30 ac = 27 ac
- MS4 loading = 27/50 x 10,000,000 = **5,400,000** # per day
- LA = 16,000,000 – 5,400,000 = 10,600,000

Example MS4 WLA calculation for Option 2

- Total TMDL: 17021276.6 # per day
- Future allocation (1%) = 170,212.7 # per day
- MOS (5%) = 851,063.8 # per day
- Total Loadings for allocation = 1,600,000 # per day
- Loading from urban land = 10,000,000 # per day
- Loading from nonurban land = 6,000,000 # per day
- Urban landuse = 50 ac
- MS4 regulated area = 30 ac
- MS4 loading = 30/50 x 10,000,000 = **6,000,000** # per day
- LA = 16,000,000 – 6,000,000 = 10,000,000

The resulting daily loadings (Counts per day) for Option 1

TMDL		LA		WLA		FA (1%)		MOS (5%)
17,021,276.6	=	10,600,000	+	5,400,000	+	170,212.7	+	851,063.8
MS4 James City (VAR040037) = 5,400,000 (aggregated wasteload allocation)								
VDOT (VAR040115)								

The resulting daily loadings (Counts per day) for Option 2

TMDL		LA		WLA		FA (1%)		MOS (5%)
17,021,276.6	=	10,000,000	+	6,000,000	+	170,212.7	+	851,063.8
MS4 James City (VAR040037) = 6,000,000 (aggregated wasteload allocation)								
VDOT (VAR040115)								

Public Participation Steps

- **First Public Meeting** (7/28/2015)
  - Shared and gathered information
  - Public comment period ended 08/29/2015

We are here

- **Technical Advisory Committee** (1/19/2016)
  - Review the source assessment estimates
  - Gather feedback and technical advice (by 2/2/16)
  - Review preliminary model calibration
  - Discuss the next steps of TMDL development

- **Final Public Meeting** (tentative Spring, 2016)
  - Report TMDL results and post draft TMDL document on the DEQ website
  - 30-day public comment period on draft TMDL

Next Phase

- Information needed
  - Confirmation of livestock
  - Information on straight pipes
  - Information on seasonal variation of wildlife
  - Feeback from TAC on estuarine model calibration
  - Any other information useful for model?

  Please provide the above information in 2-weeks (by 2/2/16) . After confirming above, we model calibration and TMDL development.
- VIMS will continue work on refining the model calibration for the freshwater segments and work on estuary bacterial model

Questions, Comments, and Information

- Contribute your input and questions on bacteria sources
  - Wildlife density, livestock, failing septic facilities, etc.
- Loading estimation
- Model calibration
- TMDL calculation
- Other questions/comments

This presentation will be made available at the DEQ web site at:

www.deq.virginia.gov

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Thanks!

Appendix

Enterococci Impaired Waters

Stream and Assessment Unit	Impairment Description	Listing Date	County	Designated Uses
Chickahominy River G08E-04-BAC VAP-G08E_CHK02A00	The Chickahominy River from the confluence with Diascund Creek downstream to the James River. (5.92 mi^2)	2006	Charles City & James City	Recreation
Diascund Creek G08E-03-BAC VAP-G08E_DSC01A00	Diascund Creek from the Diascund Reservoir dam to the mouth at the Chickahominy River. (0.27 mi^2)	2010	James City & New Kent	
Gordon Creek G08E-05-BAC VAP-G08E_GOR01A06	Tidal limit to mouth (0.2 mi^2)	2012	James City	

E. coli Impaired Waters

Stream Name and Assessment Unit	Impairment Description	Listing Date	County	Designated Use
Beaverdam Creek G09R-01-BAC VAP-G09R_BDM01A98	Beaverdam Creek from its headwaters to the upstream limit of Diascund Reservoir. (4.34 mi^2)	2012	New Kent	Recreation
XAH-Beaverdam Creek, UT G09R-06-BAC VAP-G09R_XAH01A12	Headwaters to mouth at Beaverdam Creek. (2.23 mi^2)	2012		
Diascund Creek G09R-02-BAC VAP-G09R_DSC01A00	Diascund Creek from its headwaters to the upstream limit of Diascund Creek Reservoir. (6.88 mi^2)	2008		
Mill Creek G08R-02-BAC VAP-G08R_MCR01A04	Mill Creek from its headwaters downstream to its tidal limit. (4.81 mi^2)	2004	James City	
Barrows Creek G08R-05-BAC VAP-G08R-BRW01A14	Headwaters to tidal limit. (6.93 mi^2)	2014	Charles City	

Source Assessment Summary --- Lower Chickahominy Rive*

Impaired Water	Source		Number	Fecal Coliform Load (Count/Day)	Percentage of Total Load
Lower Chickahominy River (Subwatersheds 1-26)	Wildlife	Deer	3971	2.0E+12	2.6%
		Ducks	629	1.5E+12	2.0%
		Geese	809	4.0E+13	51.9%
		Beavers	1120	2.8E+11	0.4%
		Raccoons	4184	5.2E+11	0.7%
		Muskrats	168488	5.7E+12	7.5%
		Totals	179199	5.0E+13	65.1%
	Livestock	Totals	1143	1.5E+13	19.8%
	Pets	Dogs	2136	2.0E+12	2.6%
	Humans	Septic Tank Failures	4314	2.9E+12	3.8%
		Boating	1718	1.0E+12	1.3%
		Straight Pipes	96	1.8E+12	2.3%
		Biosolids	6644 (tons)	2.9E+12	3.8%
		SSOs	8	8.7E+11	1.1%
	Totals			7.6E+13	100%

* Based on TAC feedback, these numbers and % load contributed are subject to change.

Source Assessment Summary --- Diascund Creek (Tidal)*

Impaired Water	Source		Number	Fecal Coliform Load (Count/Day)	Percentage of Total Load
Diascund Creek (Tidal) (Subwatersheds 1-6, 9-11)	Wildlife	Deer	1575	7.9E+11	3.2%
		Ducks	245	6.0E+11	2.4%
		Geese	315	1.5E+13	63.0%
		Beavers	393	9.8E+10	0.4%
		Raccoons	1660	2.1E+11	0.8%
		Muskrats	42675	1.5E+12	5.9%
		Totals	46863	1.9E+13	75.8%
	Livestock	Totals	246	2.4E+12	9.8%
	Pets	Dogs	998	9.4E+11	3.8%
	Humans	Septic Tanks	2011	1.4E+12	5.6%
		Boating	458	2.7E+11	1.1%
		Straight Pipes	52	9.6E+11	3.9%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			2.4E+13	100%

* Based on TAC feedback, these numbers and % load contributed are subject to change.

Source Assessment Summary --- Gordon Creek*

Impaired Water	Source		Number	Fecal Coliform Load (Count/Day)	Percentage of Total Load
Gordon Creek (Subwatershed 22)	Wildlife	Deer	93	4.6E+10	2.5%
		Ducks	19	4.7E+10	2.6%
		Geese	25	1.2E+12	66.3%
		Beavers	67	1.7E+10	0.9%
		Raccoons	110	1.4E+10	0.8%
		Muskrats	7995	2.7E+11	14.9%
		Totals	8308	1.6E+12	88.0%
	Livestock	Totals	26	9.3E+10	5.1%
	Pets	Dogs	27	2.5E+10	1.4%
	Humans	Septic Tanks	195	2.7E+10	1.5%
		Boating	100	6.0E+10	3.3%
		Straight Pipes	1	1.4E+10	0.8%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			1.8E+12	100%

* Based on TAC feedback, these numbers and % load contributed are subject to change.

Source Assessment Summary --- Diascund Creek*

Impaired Water	Source		Number	Fecal Coliform Load (Count/Day)	Percentage of Total Load
Diascund Creek (Non-Tidal) (Subwatershed 1)	Wildlife	Deer	434	2.2E+11	3.9%
		Ducks	63	1.5E+11	2.8%
		Geese	81	4.0E+12	72.0%
		Beavers	33	8.3E+09	0.1%
		Raccoons	449	5.6E+10	1.0%
		Muskrats	8220	2.8E+11	5.1%
		Totals	9281	4.7E+12	85.0%
	Livestock	Totals	1	0.0E+00	0.0%
	Pets	Dogs	371	3.5E+11	6.3%
	Humans	Septic Tanks	268	1.9E+11	3.4%
		Boating	4	2.2E+09	0.0%
		Straight Pipes	15	2.9E+11	5.3%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			5.5E+12	100%

* Based on TAC feedback, these numbers and % load contributed are subject to change.

Source Assessment Summary --- Beaverdam Creek*

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Impaired Water	Source		Number	Fecal Coliform Load (Count/Day)	Percentage of Total Load
Beaverdam Creek (Subwatersheds 2, 3)	Wildlife	Deer	200	1.0E+11	4.0%
		Ducks	29	6.9E+10	2.8%
		Geese	37	1.8E+12	72.2%
		Beavers	32	7.9E+09	0.3%
		Raccoons	202	2.5E+10	1.0%
		Muskrats	4274	1.5E+11	5.8%
		Totals	4773	2.1E+12	86.2%
	Livestock	Totals	1	0.0E+00	0.0%
	Pets	Dogs	148	1.4E+11	5.6%
	Humans	Septic Tanks	126	8.8E+10	3.5%
		Boating	1	4.1E+08	0.0%
		Straight Pipes	6	1.2E+11	4.7%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			2.5E+12	100%

* Based on TAC feedback, these numbers and % load contributed are subject to change.

Impaired Water	Source		Number	Fecal Coliform Load (Count/Day)	Percentage of Total Load
Beaverdam Creek, UT (Subwatershed 3)	Wildlife	Deer	64	3.2E+10	4.1%
		Ducks	9	2.2E+10	2.8%
		Geese	12	5.8E+11	73.6%
		Beavers	11	2.7E+09	0.3%
		Raccoons	65	8.2E+09	1.0%
		Muskrats	1381	4.7E+10	6.0%
		Totals	1543	6.9E+11	87.8%
	Livestock	Totals	0	0.0E+00	0.0%
	Pets	Dogs	47	4.4E+10	5.6%
	Humans	Septic Tanks	20	1.4E+10	1.8%
		Boating	0	2.6E+08	0.0%
		Straight Pipes	2	3.7E+10	4.7%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			7.9E+11	100%

Impaired Water	Source		Number	Fecal Coliform Load (Count/Day)	Percentage of Total Load
Mill Creek (Subwatershed 11)	Wildlife	Deer	221	1.1E+11	2.0%
		Ducks	38	9.2E+10	1.7%
		Geese	48	2.4E+12	43.7%
		Beavers	23	5.9E+09	0.1%
		Raccoons	241	3.0E+10	0.6%
		Muskrats	6665	2.3E+11	4.2%
		Totals	7237	2.8E+12	52.2%
	Livestock	Totals	174	2.1E+12	39.0%
	Pets	Dogs	82	7.8E+10	1.4%
	Humans	Septic Tanks	400	2.6E+11	4.8%
		Boating	5	2.7E+09	0.0%
		Straight Pipes	8	1.3E+11	2.5%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			5.4E+12	100%

Impaired Water	Source		Number	Fecal Coliform Load (Count/Day)	Percentage of Total Load
Barrows Creek (Subwatershed 17)	Wildlife	Deer	192	9.6E+10	1.2%
		Ducks	25	6.0E+10	0.8%
		Geese	32	1.6E+12	19.9%
		Beavers	32	7.9E+09	0.1%
		Raccoons	133	1.7E+10	0.2%
		Muskrats	5667	1.9E+11	2.5%
		Totals	6079	1.9E+12	24.7%
	Livestock	Totals	151	4.3E+12	55.4%
	Pets	Dogs	78	7.3E+10	0.9%
	Humans	Septic Tanks	114	7.8E+10	1.0%
		Boating	2	1.2E+09	0.0%
		Straight Pipes	2	4.2E+10	0.5%
		Biosolids	2329	1.0E+12	12.8%
		SSOs	1	3.5E+11	4.5%
	Totals			7.8E+12	100%

Source Assessment Summary --- by County*

* Based on TAC feedback, these numbers and % load contributed are subject to change.

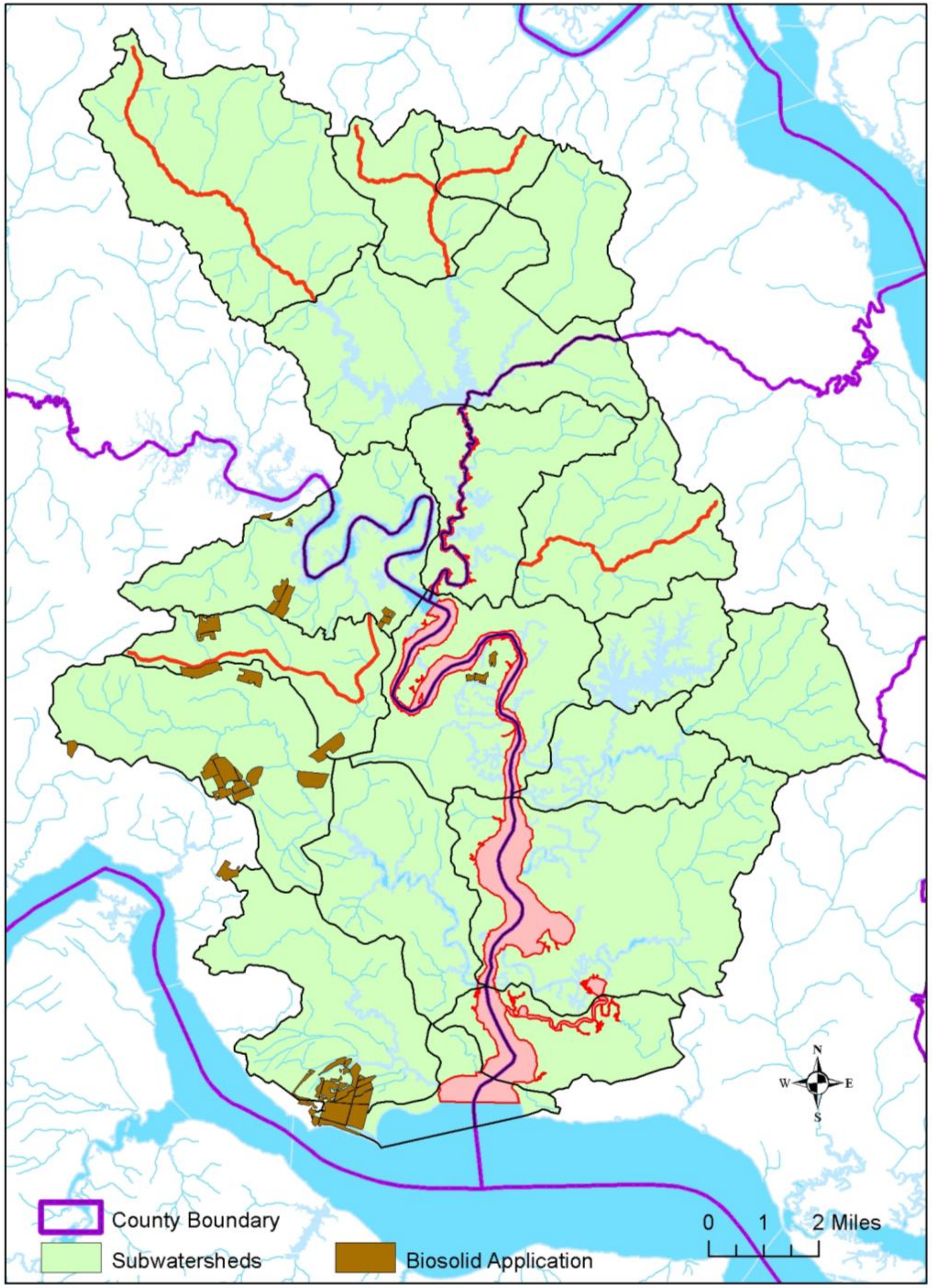
County	Source		Number	Fecal Coliform Load (Counts/Day)	Percentage
Charles City (Subwatersheds 7, 16-20, 23-25)	Wildlife	Deer	1426	7.1E+11	2.4%
		Ducks	194	4.7E+11	1.6%
		Geese	250	1.2E+13	40.6%
		Beavers	265	6.6E+10	0.2%
		Raccoons	1320	1.7E+11	0.5%
		Muskrats	58642	2.0E+12	6.6%
		Totals	62098	1.6E+13	51.9%
	Livestock	Totals	484	9.1E+12	30.4%
	Pets	Dogs	781	7.3E+11	2.4%
	Humans	Septic Tanks	488	3.1E+11	1.0%
		Boating	402	2.4E+11	0.8%
		Straight Pipes	14	2.6E+11	0.9%
		Biosolids	6644 (tons)	2.9E+12	9.7%
		SSOs	8	8.7E+11	2.9%
	Totals			3.0E+13	100%

County	Source		Number	Fecal Coliform Load (Counts/Day)	Percentage
James City (Subwatersheds 5, 10-15, 21, 22, 26)	Wildlife	Deer	1314	6.6E+11	2.2%
		Ducks	250	6.1E+11	2.1%
		Geese	321	1.6E+13	53.9%
		Beavers	483	1.2E+11	0.4%
		Raccoons	1608	2.0E+11	0.7%
		Muskrats	79133	2.7E+12	9.2%
		Totals	83108	2.0E+13	68.5%
	Livestock	Totals	653	6.0E+12	20.4%
	Pets	Dogs	464	4.4E+11	1.5%
	Humans	Septic Tanks	2331	1.5E+12	5.3%
		Boating	750	4.5E+11	1.5%
		Straight Pipes	45	7.9E+11	2.7%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			2.9E+13	100%

County	Source		Number	Fecal Coliform Load (Counts/Day)	Percentage
New Kent (Subwatersheds 1-4, 6, 8, 9)	Wildlife	Deer	1231	6.2E+11	3.6%
		Ducks	185	4.5E+11	2.7%
		Geese	238	1.2E+13	68.8%
		Beavers	371	9.3E+10	0.5%
		Raccoons	1256	1.6E+11	0.9%
		Muskrats	30713	1.0E+12	6.2%
		Totals	33993	1.4E+13	82.7%
	Livestock	Totals	5	3.8E+09	0.0%
	Pets	Dogs	891	8.4E+11	4.9%
	Humans	Septic Tanks	1494	1.0E+12	6.2%
		Boating	565	3.4E+11	2.0%
		Straight Pipes	37	7.0E+11	4.1%
		Biosolids	0	0.0E+00	0.0%
		SSOs	0	0.0E+00	0.0%
	Totals			1.7E+13	100%

Point Source – Biosolids

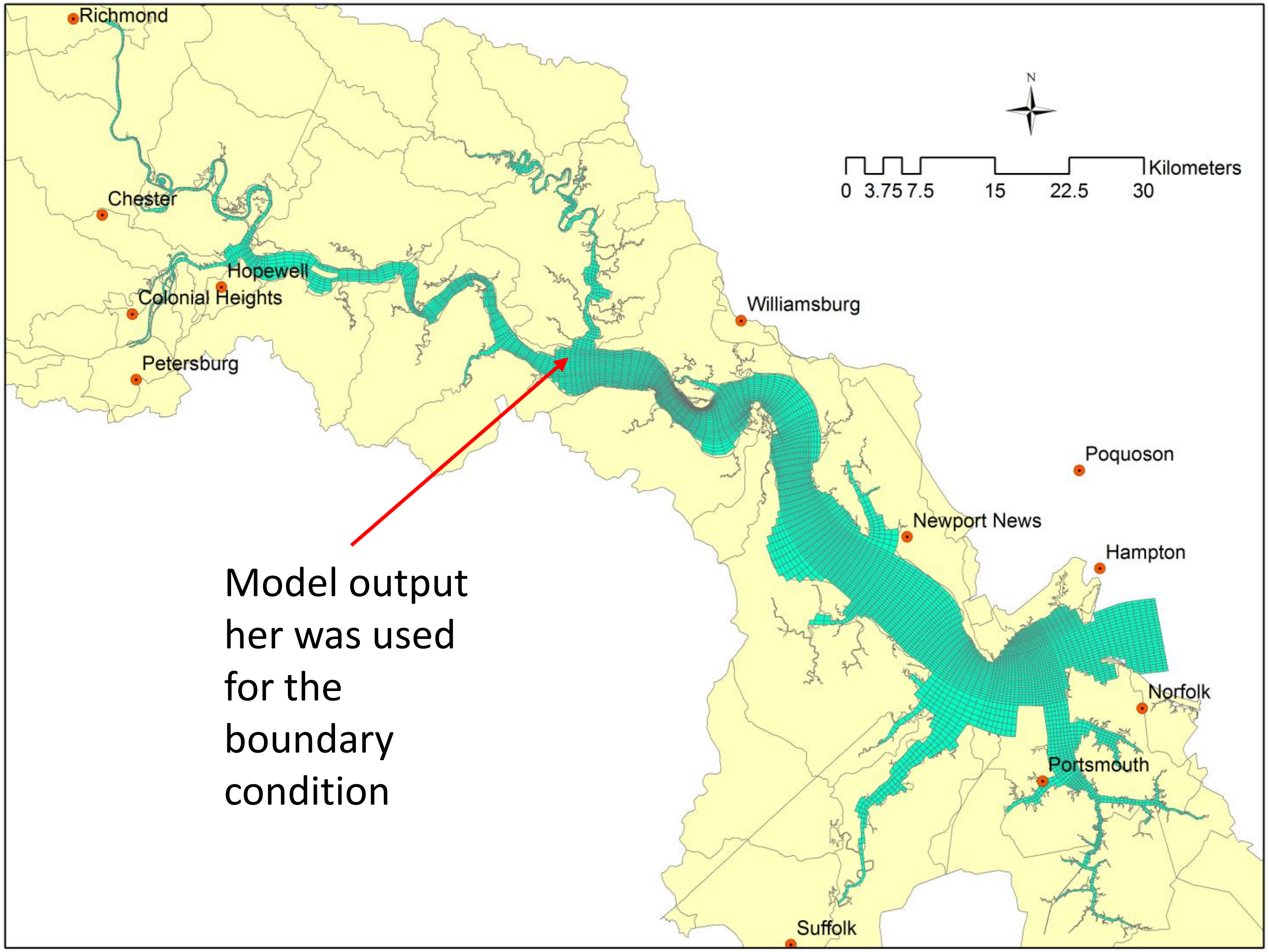
Total Area of Application
=
1503.5 Acres



James River Model

- The James River 3D model uses the EFDC model, which has been used to study sea level rise in James by USGS (Rice et al., 2011). Simulated changes in salinity in the York and Chickahominy Rivers result from projected sea-level rise in Chesapeake Bay. USGS Open-File Report 2011e1191, 31 p. http://pubs.usgs.gov/of/2011/1191/), and DEQ for James River algal study.
- The model is forced by freshwater, tide, salinity, and wind. There are 8 vertical layers. The model has been calibrated and verified. Please refer to the above reference for a detailed description of the model.
- EFDC model (Environmental Fluid Dynamic Code) (http://www.epa.gov/exposure-assessment-models/environment-fluid-dynamics-code-efdc-download-page)

James River Model Grid



Available Observation Date*

Station Id	Stream Name	Count	Average	Standard Deviation	Minimum	Maximum	Monitoring Period
2-BDM003.16	Beaverdam Creek	9	311	395	100	1300	4/29/2009-12/14/2009
2-BDM004.12	Beaverdam Creek	20	208	362	1	1700	1/4/2007-12/14/2009
2-BDM004.60	Beaverdam Creek	9	267	218	100	700	4/29/2009-12/14/2009
2-BDM005.70	Beaverdam Creek	9	500	394	100	1000	4/29/2009-12/14/2009
2-BRW002.50	Barrows Creek	12	444	684	25	2000	1/10/2011-12/10/2012
2CXAH000.35	Beaverdam Creek, UT	6	367	513	100	1400	4/29/2009-12/14/2009
2-DSC012.67	Diascund Creek	31	168	445	3	2500	7/2/2003-8/6/2004
2-MCR002.38	Mill Creek	24	271	338	25	1450	2/9/2009-12/9/2013

* Contact DEQ or VIMS to obtain observation data

Station Id	Count	Average	Standard Deviation	Minimum	Maximum	Monitoring Period
2CDSC003.11	1	10		10	10	6/27/2011
2-DSC003.19	22	120	82	25	400	3/1/2007-12/16/2014
2-DSC005.38	12	233	257	100	1000	1/13/2014-12/16/2014

Stream Name	Station Id	Count	Average (#/100mL)	Standard Deviation	Minimum	Maximum	Monitoring Period
Chickahominy River	2CCHK002.10	1	50		50	50	7/16/2008
	2CCHK004.74	1	130		130	130	6/21/11
	2CCHK006.68	1	10		10	10	7/7/14
	2CCHK015.28	1	20		20	20	7/1/13
	2CXAC000.20	1	70		70	70	7/21/08
	2-CHK000.77	1	30		30	30	7/10/07
	2-CHK001.27	1	10		10	10	8/12/04
	2-CHK002.17	64	62	94	10	700	7/2/2003-2/3/2015
	2-CHK004.82	1	10		10	10	7/10/2007
	2-CHK006.14	95	91	218	10	2000	2/20/2007-3/12/2015
	2-CHK014.33	24	119	58	25	300	1/4/2007-12/16/2014